PB-232 209

DEVELOPMENT OF A METHODOLOGY TO ALLOCATE LIQUID FOSSIL FUEL CONSUMPTION BY COUNTY

Josette C. Goldish, et al

Abcor, Incorporated

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Methods were developed for the routine determination of distillate and residual oil consumption by industrial, commercial, and residential consumers, as well as for gasoline and diesel fuel consumed by light and heavy duty motor vehicles. The resulting data are allocated to counties for input and storage in the National Emissions Data System (NEDS) area source format. In addition, seasonal fluctuations of fuel oil use by consumer category and geographic region, and references for determining sulfur content of fuel oils on a county basis, were analyzed. The report summarizes the methodologies that were developed and describes the computer processing techniques for reporting the data.

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I. INTRODUCTION

A. BACKGROUND

The Environmental Protection Agency has developed an extensive nationwide data base providing air pollutant emission estimates for area and point sources. The data in this National Emission Data System (NEDS) need to be updated on a regular basis to provide significant statistics to the EPA and other branches of government. The data on point sources will continue being updated by means of legal reporting requirements for point sources, using questionnaires and/or personal contacts with the establishments concerned. It was found necessary, however, to obtain a more routine method of updating the area source data.

This project includes the development of a methodology, whereby annual fuel oil consumption by stationary sources and motor vehicles can be collected by the EPA on a continuing basis, and allocated to individual counties. The resulting county-wide fuel oil figures will serve to update similar figures of previous years, presently available in NEDS format. It is expected that up-to-date air pollution emissions from area sources burning fuel oil can be derived from these consumption figures.

B. STUDY OBJECTIVES AND LIMITATIONS

The purpose of this contract effort was to develop a method whereby annual fuel oil consumption data could be routinely collected by the EPA on a continuing basis and allocated to individual counties with a probable error of 10 percent or less. The methods which have been developed for each county determine distillate and residual oil consumed by industry,

commerce and residential units, as well as gasoline and diesel consumed by light and heavy-duty vehicles. For the purpose of this study, residential units in structures of 20 units or more were considered under the commercial category. Furthermore, it was assumed that all on-highway use of diesel is consumed by heavy-duty vehicles.

In addition, seasonal fluctuations of fuel oil use were studied by user category and geographical region, and a collection of references on sulfur content in fuel oil were analyzed.

The first phase of the study developed the methodology to be used, and applied the methods to selected counties. These counties were selected to include examples of urban as well as rural areas, high as well as low fuel oil use areas, a variety of climates and regional economic structures. The 13 selected counties were:

Belknap, New Hampshire
Franklin, Massachusetts
Worcester, Massachusetts
Baltimore, Maryland
Palm Beach, Florida
St. Louis, Missouri
Minnehaha, South Dakota
King, Washington
Galveston, Texas
Jefferson, Alabama
Boulder, Colorado
Los Angeles, California
San Diego, California

The second phase included the collection and processing of 1972 data for all counties. This report describes the results of the first phase of the project. The results of the second phase are available in the form of a computer listing and magnetic tapes.

The basis of the approach used by Walden to arrive at the county allocation methods was the development of linear correlations between fuel use and other demographic and economic factors. Statewide fuel oil data were distributed to the counties within each state, based on the developed correlations.

The limitations of the resulting methods are summarized below:

(1) Statewide fuel oil data were found to be incomplete and not available by the categories required for this study. Methods had to be developed, therefore, to reduce the available information to the required categories. This meant that, aside from the inaccuracy of some of the published state data, an additional error factor was introduced in the figures which were used as the basis for the county-wide allocation methods.

(2) It was hoped that independent checks would be possible for several of the 13 selected counties. Walden was only able to perform rough checks on the resulting figures, since the data which would permit a more accurate validation process were not available or could not be made available.

(3) In the majority of the states, it is estimated that the developed county-wide figures have an accuracy of 10 to 15 percent. In some states, however, the statewide figures were quite inaccurate, making it practically impossible to determine the accuracy of the developed county figures.

(4) The fuel crisis confronted by the United States during 1973-1974 has resulted in significant changes in the fuel consumption patterns across the nation. Lower thermostat settings in homes and businesses, shorter working hours, and the unavailability of motor fuels as well as lower driving speeds will have altered some of the numerical values of the historical correlative relationships developed here.

II. SUMMARY

A. DATA BASE

Whenever possible, Walden has attempted to use data which appear annually or more frequently. Table 2-1 summarizes the major sources used. Table 2-2 specifies the contacts made with the various state highway administration offices throughout the country.

Other data sources are referenced throughout this report, but the sources in Tables 2-1 and 2-2 are essential to prepare the input to the computer programs containing the methods developed to allocate fuel oil to individual counties.

The data base is divided into two major categories:

(1) state data

(2) county data

The state data include fuel oil figures, as well as socio-economic and demographic variables. The county data include solely the latter. The basic state fuel oil figures used were taken from the Bureau of Mines Annual Fuel Oil Sales publication, for stationary sources, and from Highway Statistics, published yearly by the Federal Highway Administration, for mobile sources.

The seasonal fluctuations data were taken from climatological reports (1) and summaries made from NEDS industrial point source data.

TABLE 2-1

SOURCES REQUIRED FOR INPUT PREPARATION
COUNTY-WIDE FUEL OIL ALLOCATION PROGRAMS

Source	Approximate Date Available	Used For	Cost	Way to Obtain
Fuel Oil Sales, Annual, Bureau of Mines, Washington, D.C.	Mid-October	all stationary statewide distillate and residual of previous year	---	Mr. James M. Diehl, Fossil Fuel Division, Bureau of Mines, Washington D.C., Telephone: (703) 557-0443
1970 Census of Housing - Detailed Characteristics, U.S. Dept. of Commerce, Washington, D.C.	completed by mid-1972 (published every 10 years)	residential housing units using oil, % aptmts, % rural	$111.00	U.S. Government Printing Office, Washington, D.C. 20402
Fuel Oil and Oil Heat, Cedar Grove, New Jersey	monthly - specific data in October issue	residential - oil burners by state	$7/year $12/2 years	Doris Spelshouse, Subscription Manager, 200 Commerce Road, Cedar Grove, N.J. 07009 Telephone: (201) 239-5800
Local Climatological Data, Annual Summary with Comparative Data, U.S. Dept. of Commerce, Nat'l Climatic Center, Asheville, N.C.	Annual available April	residential - degree-days	15 cents per copy	U.S. Dept. of Commerce, Nat'l Climatic Center, Federal Bldg., Asheville, N.C. 28801
Climatological Data, Monthly Summarized Station and Divisional Data, U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, Asheville, N.C.	Monthly	residential - degree-days	20 cents per copy	U.S. Dept. of Commerce, Nat'l Climatic Center, Federal Bldg., Asheville, N.C. 28801

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TABLE 2-1 (CONTINUED)

Source	Approximate Date Available	Used For	Cost	Way to Obtain
1970 Census of Population, Number of Inhabitants, U.S. Dept. of Commerce, Washington, D.C.	Completed by May 1972 (published every 10 years)	Mobile sources population by county	$20.75 two volumes	U.S. Government Printing Office, Washington, D.C. 20402
1970 Census of Housing - General Characteristics, U.S. Dept. of Commerce, Washington, D.C.	Published December 1971 (published every 10 years)	residential - avg. rooms per housing unit	$61.35	U.S. Government Printing Office Washington, D.C. 20402
County Business Patterns, U.S. Dept. of Commerce, Washington, D.C.	August, yearly	commercial and industrial - employment	$89.40	U.S. Government Printing Office, Washington, D.C. 20402
Highway Statistics, U.S. Dept. of Transportation, Federal Highway Administration, Washington, D.C.	November - March, yearly (varies from year to year)	mobile sources statewide gasoline, diesel, registrations, vehicle miles	$ 2.50	U.S. Government Printing Office Washington, D.C. 20402
Road-User and Property Taxes on Selected Motor Vehicles, 1970, U.S. Dept. of Transportation, Federal Highway Administration, Bureau of Public Roads	Published every three years	Mobile sources - miles per gallon, etc.	65 cents	U.S. Government Printing Office, Washington, D.C. 20402
Census of Transportation, Bureau of Census, Washington, D.C.	Published every five years	trucks by weight categories	$ 7.25	U.S. Government Printing Office, Washington, D.C. 20402
R.L. Polk Countywide automobile and truck registrations	yearly		EPA contract	

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TABLE 2-1 (CONTINUED)

Source	Approximate Date Available	Used For	Cost	Way to Obtain
Motor Truck Facts, Automobile Manufacturers Association, New York, N. Y.	Yearly	Avg. gallons for bus categories	---	Automobile Manufacturers Association New York, N. Y. Telephone: (212) 682-5800
Mineral Yearbook, Volume I Bureau of Mines, Washington, D. C.	Annual, 2 year lag	Commercial use of Bituminous coal	$6.00	U. S. Government Printing Office, Washington, D. C. 20402
Gas Facts, American Gas Association, Washington, D. C.	Annual	Commercial use of piped gas	$4.00	American Gas Association 1515 Wilson Blvd. Arlington, Virginia 22209
Census of Manufactures, Special Report Series: Fuels and Electric Energy Consumed, U. S. Department of Commerce, Washington, D. C.	every 5 years (possibly annual in future) 2 year lag	Industrial use of oil	$1.25	U. S. Government Printing Office Washington, D. C. 20402

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TABLE 2-2

SOURCES CONTACTED FOR VEHICLE MILE DATA

State	Extent of Data Available	Department, Name of Contact, Tel. No.	Date Available
Maine	Vehicle mile totals for all roads by county	Dept. of Transportation, Bureau of Transportations Services, Mr. Picher Telephone: (207) 289-3131	Data for previous year available in August or September
Vermont	Vehicle mile totals for all roads by county for 1970 only	Department of Transportation Highway Planning Division, Mr. Leach Telephone: (802) 828-2671	
New Hampshire	No vehicle mile data or related information available on a county basis	State Dept. of Public Works Planning and Economics Division, Mr. Lee Telephone: (603) 271-3344	
Massachusetts	No vehicle mile data or related information available on a county basis	Dept. of Public Works Planning Office, Mr. Genino Telephone: (617) 727-5124	
Rhode Island	No vehicle mile data or related information available on a county level	Dept. of Public Works State Traffic Engineer Telephone: (401) 277-2694	
Connecticut	No vehicle mile data or related information available on a county level	Dept. of Transportation, Bureau of Planning and Research, Mr. Bark Telephone: (203) 566-2414	
*New York	No vehicle mile data or related information available on a county level	Dept. of Transportation, Office of Planning and Development, Mr. Tweedis Telephone: (518) 457-5540	

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TABLE 2-2 (CONTINUED)

State	Extent of Data Available	Department, Name of Contact, Tel. No.	Date Available
Pennsylvania	Annual vehicle mile figures by county for state roads only	Dept. of Transportation, Bureau of Trans. Planning Statistics, Mr. May Telephone: (717) 787-5983	Data for previous year available during summer
Deleware	Annual vehicle mile figures by county for all roads	Bureau of Highway Planning Mr. Shoe Telephone: (302) 678-4343	Data for previous year available during summer
New Jersey	Annual vehicle mile figures by county for state roads only	State Highway Department, Planning Division, Mr. Green Telephone: (609) 292-3530	Data for previous year available during summer
Maryland	State road mileage figures traffic counts for certain roads "Traffic Trends" annual	State Highway Administration Office of Planning, Mr. Cloonan Telephone: (301) 383-4436	Data for previous year available by September
Ohio	Annual vehicle mile figures by county for state roads only "Ohio Highway Mileage Report"	State Dept. of Highways, Division of Planning & Programming, Mr. Whilkins Telephone: (614) 469-2617	Data for previous year available in February or March
Michigan	No data on vehicle mile figures kept by county or related information	Dept. of State Highways, Transportation Planning Division Telephone: (517) 373-2663	
West Virginia	Vehicle mile figures by county for state roads, special study 1971 only	West Virginia Dept. of Highway Advanced Planning Division, Mr. Brennan Telephone: (304) 348-3113	
Virginia	No data on vehicle miles kept by county or any related data	State Dept. of Highways, Div. of Traffic and Planning Telephone: (703) 770-2876	
Kentucky	Annual vehicle mile data by county for all roads, total of all counties fall appreciably short of statewide total as given in FHWA "Highway Statistics"	Dept. of Highways, Division of Planning Statistical Section, Mr. Blackmore Telephone: (502) 564-2500	Data for previous year available in June or July

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TABLE 2 (CONTINUED)

State	Extent of Data Available	Department, Name of Contact, Tel. No.	Date Available
Indiana	No data on vehicle miles kept by county or any related data	State Highway Commission Technical Services Telephone: (317) 633-5816	
Illinois	Vehicle miles figures by county for all roads every 3 years	Division of Highways, Bureau of Research and Development, Mr. Tornton Telephone: (217) 525-7748	Data for 1971 available April or May, 1973; next data will be for 1974
Wisconsin	Annual vehicle mile data for all roads by county, has not been received yet	Dept. of Transportation, Division of Planning, Mr. Pamperin Telephone: (414) 266-2752	
Tennessee	No data on vehicle miles kept by county or any related data	Dept. of Highways, Research & Planning Bureau, Mr. Werpool Telephone: (615) 741-3687	
North Carolina	No data on vehicle miles kept by county or any related data	State Highway Commission, Dept. of Planning and Research, Mr. Former Telephone: (919) 829-3141	
South Carolina	No data on vehicle miles kept by county or any related data	State Highway Dept., Traffic and Planning Division, Mr. Hammand Telephone: (803) 758-3370	
Georgia	Special report on 1971 vehicle mile figures for all roads by county, no material on an annual basis	State Highway Dept., Division of Highway Planning, Mr. Tenkin Telephone: (404) 656-5460	
Texas	Annual vehicle mile data by county for all roads; must request by mail	Dept. of Highways, Research and Planning Bureau, Planning Survey Div., Mr. Wright Telephone: (512) 475-4846	Data for previous years available in June or July
Alabama	No data on vehicle miles kept by county for all roads; must request by mail	State Highway Dept., Bureau of Research and Development, Mr. Lee Telephone: (205) 269-7312	

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TABLE 2-2 (CONTINUED)

State	Extent of Data Available	Department, Name of Contact, Tel. No.	Date Available
Mississippi	Annual vehicle mile data by county for state roads only	State Highway Dept., Traffic and Planning Division, Mr. Livingston Telephone: (601) 354-7172	Data available in late summer of following year
Lousiana	Annual vehicle mile figures for state roads only in "Annual Report, Lousiana State Highways"	Dept. of Highways, Traffic and Planning Division, Mr. Reeves Telephone: (504) 389-5341	Data available in September of following year
Florida	Annual gasoline sales figures by county, based on tax receipts, for fiscal year ending in June	Dept. of Transportation, Division of Transportation Planning, Mr. Freggar Telephone: (904) 488-4111	Data for previous year available in February
New Mexico	Annual vehicle mile data by county for all roads in "New Mexico Traffic Survey"	State Highway Dept., Planning and Programming Dept., Mr. Beechum Telephone: (505) 983-7381	Data for previous year available in July
Arizona	Annual vehicle mile data by county for state roads only	State Highway Dept., Planning and Survey Division, Mr. Green Telephone: (602)261-7252	Data for previous year available in March
Nevada	Annual vehicle mile figures by county for all roads; in "Status of Road Systems"	Dept. of Highways, Planning Survey Division, Mr. Ross Telephone: (702) 882-7080	Data for previous year available July 1
Arkansas	Annual vehicle mile data by county for all roads	Dept. of Highway Planning and Research Division, Mr. Bingam Telephone: (501) 569-2426	Data for previous year available in June
Oklahoma	No data on vehicle miles kept by county or any related data	Dept. of Highways Current, Current Planning Division Telephone: (405) 521-2575	
Iowa	Annual vehicle mile dat by county for all roads	State Highway Commission, Division of Planning, Mr. Studder Telephone: (515) 296-1306	Data for previous year available in December

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TABLE 2-2 (CONTINUED)

State	Extent of Data Available	Department, Name of Contact, Tel. No.	Date Available
Nebraska	No data on vehicle miles by county available on any related data	State Highway Dept., Programming and Planning Division Telephone: (402) 477-6012	
Kansas	Annual vehicle mile data by county for all roads	State Highway Commission, Planning and Development Division, Mr. Sutton Telephone: (913) 296-3841	Data for previous year available in July
Missouri	Annual vehicle mile data for state roads only	State Highway Dept., Planning Section, Mr. Klamm Telephone: (314) 751-2825	Data for previous year available in the fall
Minnesota	No annual vehicle mile data available, or any related data	Dept. of Highways, Traffic Analysis Division, Mr. Gildemister Telephone: (612) 296-3147	
California	Biannual vehicle mile data available by county for all roads in "Historical State Highway, County Road and City Street Statistics"	State Dept. of Public Works, Traffic Department, Mr. Bailey Telephone: (916) 445-3127	Data for 1972 will be available in August 1973
North Dakota	Annual vehicle mile data by county for all roads in "Annual Traffic Report"	State Highway Dept., Planning and Research Division, Mr. Zinc Telephone: (701) 224-2512	Data for previous year available in May
South Dakota	Annual vehicle mile data by county for all roads	Dept. of Highways, Research and Planning Division Telephone: (605)224-3278	Data for previous year available in October or November, however there has been a delay in availability 1971 data
Colorado	No annual vehicle mile data by county or any related data	Dept. of Highway, Planning and Research Division, Mr. Doland Telephone: (303) 757-9262	

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TABLE 2-2 (CONTINUED)

State	Extent of Data Available	Department, Name of Contact, Tel. No.	Date Available
Utah	Vehicle mile data for 1971 only by county for all roads from special traffic study	State Dept. of Highways, Systems Planning Division, Mr. Jester Telephone: (801) 328-5707	
Wyoming	Annual vehicle mile data by county for state roads only	State Highway Dept., Planning and Programming Div., Mr. Caukel Telephone: (307) 777-7552	Data for previous year available in May or June
Montana	Vehicle mile figures by county for all roads; 1969 and 1971 only from special report	State Highway Commission, Planning Survey Div., Mr. Divine Telephone: (406) 449-2564	
Idaho	No annual vehicle mile data available, or any related data	State Highway Dept., Planning and Traffic Division, Mr. Sullivan Telephone: (208) 384-2591	
Washington	Annual vehicle mile data by county for all roads	State Dept. of Highways, Dept. of Planning and Research, Mr. Cummings Telephone: (206) 753-6005	Data for previous year available in May or June
Oregon	Annual vehicle mile data by county for state roads only	Dept. of Transportation, Traffic and Engineering Div., Mr. Owens Telephone: (503) 378-6277	Data for previous year available in May
Hawaii	Annual vehicle mile data by county for all roads and annual vehicle registrations by county	Dept. of Transportation, Highway Planning Division, Mr. Uehara Telephone: (808) 548-7655	Data for previous year available in fall
Alaska	Some data on gasoline sales by county available	State Dept. of Highways, Planning Division Mr. Eberhardt Telephone: (907) 364-2121	Data for previous year available in April; no data has been received at this time, however

Note: Annual contact with states that presently produce no relevant data is advisable. It is likely that an increased number of states will adopt methods to tabulate vehicle miles by county in the future, according to conversations with a number of FHWA regional engineers

Wilbur Smith

The sulfur content data were taken from Bureau of Mines publications [2,3,4], summaries made from NEDS point source data, and a survey of state and regional sulfur content data collected by the various local air pollution agencies.

B. METHOD

The Bureau of Mines fuel oil data are available by state by the categories listed in the left-hand column of Table 2-3. The categories required for the study are listed in the right-hand column of Table 2-3

TABLE 2-3

COMPARISON OF REPORTED FUEL OIL USER CATEGORIES AND REQUIRED USER CATEGORIES

Categories Used by the Bureau of Mines	Categories Required for this Program
1. Heating Oils #1, 2, 4, 5 and 6	1. Residential
2. Distillate Oil and Residual Oil Shipments for:	2. Commercial
a. industrial use	3. Industrial
b. oil company use	4. Light Duty Vehicle
c. railroad use	5. Heavy Duty Vehicle
d. vessel-bunkering use	
e. military use	
f. electric utility company use	
g. miscellaneous (including on-highway and off-highway uses for diesel)	

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It was therefore necessary to convert the available state fuel oil data to the desired categories, before attempting to allocate the oil use to the various counties. Consequently, the developed methods are discussed under two separate headings:

(1) Completion of State Data

(2) County Allocation of Fuel Oil

1. Completion of State Data

a. Residential

Various methods were examined to estimate fuel oil consumed by residential units on a statewide basis. The more sophisticated methods included variables for which the available data would have to be averaged by state. It was felt that the accuracy of such methods would be reduced by the use of the averaged data, and it was therefore decided to use the EPA method [5] to calculate statewide residential distillate oil consumption, whenever this would prove necessary,* i.e.,

Residential distillate oil (gallons) = [number of housing units using oil for spaceheating x .18 (gallons/degree-day/unit) x degree days**] + [number of housing units using oil for hot water x 250 gallons]

---

*Only necessary when not all counties within a state are being processed.

** Degree Days: A measure of the departure of the main daily temperature from 65°F: one degree day for each degree of departure below the standard of 65°F during one day.

The residential category includes only housing units in structures of less than 20 units [6], and it is therefore accurate to assume that all residential fuel oil burned is distillate oil.

b. Comercial

For the years for which the Census of Manufactures Special Report Series on Fuel and Electric Energy Consumed [8] is published the commercial oil is calculated as follows:

Commercial distillate oil = all distillate oil categories, except power plants - residential distillate oil - distillate oil used for manufacturing

Commercial residual oil = all residual oil categories, except power plants - residual oil used for manufacturing

Otherwise, the calculations are based on Bureau of Mines data [7] and data derived by Walden as summarized below:

Commercial distillate oil = [a* x (distillate oil used for heating - residential distillate oil)] + distillate oil for military use

Commercial residual oil = [a* x residual oil used for heating] + residual oil for military use

---

*a is a commercial fraction based on commercial employment
b is an industrial fraction based on manufacturing employment
a + b = 1

c. Industrial

For the years for which data are available from the Census of Manufactures report mentioned above, distillate and residual oil state totals are taken directly from that publication. Otherwise, the following calculations are performed:

Industrial distillate oil = [b* x (distillate oil used for heating - residential distillate oil)] + distillate oil for industrial use + distillate oil for oil company use

Industrial residual oil = [b* x residual oil used for heating] + residual oil for industrial use + residual oil for oil company use

d. Heavy Duty Vehicles (HDV)

Heavy duty vehicles are defined as all vehicles weighing more than 6,000 lbs gross weight. Four subcategories are considered in these calculations:

HDV_1: 6,001 - 10,000 lbs

HDV_2: 10,001 - 20,000 lbs

HDV_3: 20,001 - 26,000 lbs

HDV_4: Greater than 26,000 lbs

---

*a is a commercial fraction based on commercial employment
b is an industrial fraction based on manufacturing employment
a + b = 1

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statewide HDV gasoline use is calculated as follows:

$$\text{HDV gasoline use} = [\sum_{i=1}^{i=4} (\text{HDV}_i \times \text{average miles}_i/\text{miles per gallon}_i) + (\text{commercial buses} \times \text{average gallons/bus}) + (\text{school buses} \times \text{average gallons/bus})] - [\text{diesel and butane use}]$$

HDV diesel use by state is reported by the Federal Highway Administration [9].

e. Light-Duty Vehicles (LDV)

It is assumed that only a negligible number of light-duty vehicles use diesel.

LDV gasoline use = total gasoline sales [9] - HDV gasoline

2. <u>County Allocation of Fuel Oil</u>

a. Residential

Countywide use of residential distillate oil is calculated by means of the formula:

$$\text{Residential distillate oil use (gallons)} = (.01288 \times \text{degree-days} + 30.41 \times \text{average rooms per housing unit} - 79.54)/.14$$

This relationship was developed by Walden for this project by means of a stepwise regression analysis based on residential gas data obtained from a number of gas companies throughout the nation (see Appendix A).

b. Commercial

County-wide distribution of commercial distillate and residual oil is based on the following steps:

(1) Calculation of fuel used in each county by hospitals, hotels, schools, colleges, and laundries, based on correlative relationships between fuel use and employment developed by Walden (see Appendix B).

(2) Determination of the fractions of this fuel use attributable to distillate and residual oil based on the fuel use patterns in each state.

(3) Calculation of distillate and residual oil consumed by housing units using oil in structures of 20 units or more in each county. It was assumed that units in structures of more than 50 units consumed residual oil and that all other residential units included under the commercial category consumed distillate oil.

(4) Subtraction of the oil totals for the above six subcategories from the state totals for commercial distillate and residual oil use.

(5) Subtraction of the employment totals for the categories mentioned under (1) from the respective county and state employment totals.

(6) Allocation of the remaining state fuel oil figures by means of the adjusted county and state employment figures.

(7) Addition of the oil used by the six subcategories to the county oil figures obtained in Step 6.

c. Industrial

County-wide distribution of industrial distillate and residual oil is performed by means of industrial employment figures which have been adjusted by means of a fuel intensity factor which is industry dependent (two-digit SIC).

$$\text{Industrial fuel oil}_{\text{county } i} = \frac{\text{adjusted industrial employment}_i}{\text{adjusted industrial employment}_I} \times \text{industrial fuel oil}_{\text{state } I}$$

d. Heavy-Duty Vehicle (HDV)

County use of diesel by HDV's is obtained by using county truck registrations [10] as the apportioning factors to be applied to the state totals.

$$\text{Diesel HDV}_{\text{county } i} = \frac{\text{trucks} > 6000 \text{ lb}_i}{\text{trucks} > 6000 \text{ lb}_I} \times \text{diesel HDV}_{\text{state } I}$$

In order to determine county use of gasoline for HDV's the following calculation is performed:

$$(\text{gasoline HDV})_{\text{county } i} = \sum_{j=1}^{j=4} \text{HDV}_j \times \text{avg. miles}_{j(I)}/\text{MPG}_{j(I)}$$

$$+ \frac{\text{population (census yr)}_i}{\text{population (census yr)}_I} \times (\text{commercial buses}_I \times 7276 \text{ gallons/bus})$$

$$+ \frac{\text{population (census yr)}_i}{\text{population (census yr)}_I} \times (\text{institutional buses}_I \times 1058 \text{ gallons/bus})$$

$$- \frac{\text{trucks}_i}{\text{trucks}_I} \times (\text{diesel and butane})_I$$

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e. Light-Duty Vehicle (LDV)

The method developed for county allocation of gasoline used by LDV's is as follows:

(1) If vehicle miles are available by county they are to be used as the distributive factor in the form:

$$\text{gasoline LDV}_{\text{county } i} = \frac{\text{vehicle miles}_i}{\text{vehicle miles}_I} \times \text{total gasoline}_{\text{state I}} - \text{gasoline HDV}_i$$

(2) If vehicle mile data by county are not available, the sum of the registered automobiles and trucks under 6,000 lb in each county [10] is adjusted by means of a rural/urban miles per vehicle index and used as the distributive factor in the form:

$$\text{gasoline LDV}_{\text{county } i} = \frac{\text{LDV}_i \times \text{index}_i}{\sum_{i=1}^{i=n} (\text{LDV}_i \times \text{index}_i)} \times \text{total gasoline}_{\text{state I}} - \text{gasoline HDV}_i$$

where state i consists of n counties.

C. RESULTS FOR 13 SELECTED COUNTIES - 1970 and 1971

Tables 2-4 and 2-5 show the results of the methods summarized above for 13 selected counties for 1970 and 1971 respectively. In order to obtain these results, it was necessary to subtract point source fuel oil use from

TABLE 2-4

1970 RESULTS FOR SELECTED COUNTIES

County	Residential	Commercial		Industrial		Gasoline		
	Distillate	Distillate (thou. Barrels)	Residual	Distillate	Residual	Light Duty (thou. Gallons)	Heavy Duty	Heavy Duty Diesel
Jefferson	41	114	55	371	284	174,300	29,880	14,340
Los Angeles	38	1,595	5,163	0	6,424	2,481,000	161,500	157,800
San Diego	30	208	670	0	300	548,000	34,770	34,720
Boulder	14	39	13	21	34	49,120	5,564	3,494
Baltimore	3,272	525	1,547	593	0	430,500	33,760	19,120
Worcester	3,960	1,009	1,479	2,087	3,099	313,600	19,100	10,650
Franklin	477	100	143	104	154	19,980	2,725	1,624
St. Louis	667	351	246	278	100	79,370	10,440	4,546
Belknap	260	19	43	8	0	17,730	1,167	836
Minnehaha	112	2	7	72	12	28,900	6,108	2,452
Palm Beach	101	89	89	37	94	125,100	16,760	7,191
Galveston	1	45	8	233	92	64,160	7,708	4,770
King	3,573	1,085	1,727	0	0	459,500	21,390	21,480

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TABLE 2-5

1971 RESULTS FOR SELECTED COUNTIES

County	Residential Distillate	Commercial Distillate (Thou. Barrels)	Commercial Residual (Thou. Barrels)	Industrial Distillate	Industrial Residual	Gasoline Light Duty (thou. Gallons)	Gasoline Heavy Duty (thou. Gallons)	Heavy Duty Diesel
Jefferson	41	129	32	369	148	181,400	29,960	15,790
Los Angeles	40	2,717	3,376	0	7,586	2,731,000	154,800	171,300
San Diego	32	368	456	0	353	499,000	34,860	39,800
Boulder	15	43	11	35	42	55,120	6,035	4,240
Baltimore	3,282	658	934	533	0	467,900	34,190	19,490
Worcester	3,880	1,076	1,535	1,998	2,530	11,860	18,580	310,800
Franklin	468	106	145	100	127	1,883	2,750	26,470
St. Louis	636	361	151	306	18	87,070	10,400	5,194
Belknap	268	16	43	11	0	19,500	1,038	987
Minnehaha	79	0	1	0	9	25,230	2,466	2,765
Palm Beach	103	93	122	44	99	143,900	17,250	8,674
Galveston	1	52	6	270	71	71,080	5,722	503
King	3,909	388	1,511	0	0	469,100	32,880	24,040

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the statewide commercial and industrial fuel oil totals, and also to subtract the corresponding point source employment figures from the employment data for the 13 counties. Thus, the figures in Tables 2-4 and 2-5 are for area sources only.

Tables 2-6 and 2-7 show the seasonal fluctuation patterns for residential and commercial fuel oil use for 1970 and 1971. These figures are based solely on degree-day fluctuations. Seasonal fluctuations in industrial residual oil use are summarized in Table 2-8 by two digit SIC, and are based primarily on summaries made by Walden from NEDS point source data.

Table 2-9 shows average sulfur content for distillate and residual oil used in the selected counties in 1970 and 1971. These figures were taken from a variety of Bureau of Mines publications, as well as summaries made by Walden from NEDS point source data.

These county-wide figures are available for all counties of the United States and Puerto Rico for 1972 in the form of a computer printout and NEDS area source punched cards provided to EPA-NADB, Durham, North Carolina.

TABLE 2-6

SEASONAL FLUCTUATIONS OF FUEL USE FOR RESIDENTIAL AND COMMERCIAL SPACEHEATING - 1970 (BASED ON DEGREE-DAYS)

County	Jan.-March	April-June	July-Sept.	Oct.-Dec.
Belknap, N.H.	51%	12%	3%	34%
Franklin, Ma.	51%	13%	3%	33%
Worcester, Ma.	51%	13%	3%	33%
Baltimore, Md.	59%	9%	0%	32%
Palm Beach, Fl.	76%	0%	0%	24%
St. Louis, Mo.	57%	7%	0%	36%
Minnehaha, S.D.	51%	10%	3%	36%
King, Wa.	37%	20%	6%	37%
Galveston, Tx.	72%	2%	0%	26%
Jefferson, Al.	59%	4%	0%	37%
Boulder, Co.	45%	15%	3%	37%
Los Angeles, Ca.	48%	17%	0%	34%
San Diego, Ca.	45%	19%	0%	36%

TABLE 2-7

SEASONAL FLUCTUATIONS OF FUEL USE FOR RESIDENTIAL AND COMMERCIAL SPACEHEATING - 1971 (BASED ON DEGREE-DAYS)

County	Jan.-March	April-June	July-Sept.	Oct.-Dec.
Belknap, N.H.	50%	14%	3%	33%
Franklin, Ma.	52%	15%	2%	31%
Worcester, Ma.	52%	15%	2%	31%
Baltimore, Md.	58%	11%	1%	30%
Palm Beach, Fl.	94%	6%	0%	0%
St. Louis, Mo.	59%	9%	1%	30%
Minnehaha, S.D.	51%	10%	3%	36%
King, Wa.	40%	20%	6%	34%
Galveston, Tx.	71%	3%	0%	26%
Jefferson, Al.	63%	9%	0%	28%
Boulder, Co.	41%	16%	5%	37%
Los Angeles, Ca.	42%	15%	0%	43%
San Diego, Ca.	49%	17%	0%	34%

TABLE 2-8

SUMMARY OF SEASONAL FLUCTUATIONS OF RESIDUAL OIL USED BY INDUSTRIAL SOURCES

SIC	Industry Group	Winter	Spring	Summer	Fall
19	Ordnances	36%	22%	14%	28%
20	Food	29%	29%	21%	21%
21	Tobacco	25%	25%	25%	25%
22	Textile	28%	25%	22%	25%
23	Apparel	37%	25%	13%	25%
24	Lumber & Wood	25%	25%	25%	25%
25	Furniture	31%	25%	19%	25%
26	Paper	26%	25%	24%	25%
27	Printing	38%	23%	13%	26%
28	Chemicals	27%	25%	23%	25%
29	Petroleum	25%	25%	25%	25%
30	Rubber & Plastics	30%	25%	20%	25%
31	Leather	32%	25%	18%	25%
32	Stone, Clay, Glass	26%	25%	24%	25%
33	Primary Metals	26%	28%	24%	22%
34	Fab. Metals	28%	25%	22%	25%
35	Machinery, exc. electr.	29%	25%	20%	25%
36	Electr. Equipment	35%	24%	17%	24%
37	Transportation	40%	16%	11%	33%
38	Instruments	27%	25%	23%	25%
39	Miscellaneous	37%	25%	14%	24%

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TABLE 2-9

SULFUR CONTENT AVERAGES FOR DISTILLATE AND RESIDUAL OIL BURNED BY AREA SOURCES (percentages)

County	1970		1971	
	Distillate	Residual	Distillate	Residual
Belknap, N.H.	0.21	1.90	0.21	1.68
Franklin, Ma.	0.21	2.00	0.21	1.85
Worcester, Ma.	0.21	2.00	0.21	1.85
Baltimore, Md.	0.21	1.47	0.21	1.00
Palm Beach, Fl.	0.17	2.00	0.19	1.30
St. Louis, Mo.	0.28	1.67	0.27	1.64
Minnehaha, S.D.	0.28	1.67	0.27	1.64
King, Wa.	0.21	1.64	0.21	1.56
Galveston, Tx.	0.17	1.73	0.19	1.73
Jefferson, Al.	0.17	1.73	0.19	1.73
Boulder, Co.	0.32	2.15	0.32	2.15
Los Angeles, Ca.	0.21	1.64	0.21	1.56
San Diego, Ca.	0.21	1.64	0.21	1.56

REFERENCES - SECTION II

1. Climatological Data, monthly summarized station and divisional data, U.S. Dept. of Commerce, National Oceanographic and Atmospheric Administration, Ashville, N.C.

2. Burner Fuel Oils, Mineral Industry Surveys, Bureau of Mines, Bartlesville, Okla.

3. Fuel Oils by Sulfur Content, Mineral Industry Surveys, Bureau of Mines, Washington, D.C.

4. Oil Availability by Sulfur Levels, Bureau of Mines, Washington, D.C., 1971.

5. Guide for Compiling a Comprehensive Emission Inventory, Environmental Protection Agency, Research Triangle Park, N.C., March 1973.

6. 1970 Census of Housing - Detailed Characteristics, U.S. Dept. of Commerce, Washington, D.C.

7. Mineral Industry Surveys, Annual Fuel Oil Sales, U.S. Bureau of Mines, Washington, D.C.

8. 1972 Census of Manufactures, Special Report Series: Fuels and Electric Energy Consumed, U.S. Dept. of Commerce, Washington, D.C.

9. Highway Statistics, U.S. Dept. of Transportation, Federal Highway Administration, Washington, D.C.

10. Registration data available from R.L. Polk Co., Detroit, Mich.

III. DISCUSSION OF METHODOLOGY

A. RESIDENTIAL

1. State Fuel Oil

Four different methods were attempted to arrive at the residential use of distillate oil by state:

(1) Using EPA's suggested estimate of 0.18 gallons/unit/degree-day [1] to determine fuel oil consumed for spaceheating requirements.

(2) Using the formula:

$$\frac{\text{\# of oil burners x avg size (Btu/hr) x 8760 (hr/yr) x load}}{\text{140,000 (Btu/gallon)}}$$

to determine fuel oil consumed for spaceheating requirements [2].

(3) Using a stepwise regression analysis which included the independent variables: degree-days, price of fuel, per capita income, and average number of rooms per housing unit, to determine fuel oil consumed for spaceheating requirements.

(4) Using the formula:

$$\frac{\text{\# of oil burners x heat loss x degree-days x use factor}}{\text{140,000 Btu/gallon x design range}}$$

to determine fuel oil consumed for spaceheating requirements, where the heat loss was dependent on the average square feet per housing unit [3]. These calculations are discussed in detail in Appendix A.

Table 3-1 shows estimates for selected states of residential fuel oil used for spaceheating as calculated by each of these methods. In general, it was felt that the need to average and estimate so many of the

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TABLE 3-1

SUMMARY OF ESTIMATION METHODS FOR RESIDENTIAL FUEL OIL USED FOR SPACEHEATING BY STATE

Based on:

	EPA(1)	Equipment(2)	Multiple Regression(3)	Square Feet(4)
Massachusetts	25,678	42,005	14,896	n.a.
Maryland	9,853	10,307	7,048	n.a.
Missouri	2,494	3,466	1,234	3,236
Washington	9,533	16,109	4,786	11,062
Maine	8,700	8,326	3,951	n.a.
Connecticut	15,984	19,665	10,475	n.a.
Florida	1,927	1,389	n.a.	2,466
Alabama	128	245	n.a.	143

Sources:

(1) EPA Guide for Compiling a Comprehensive Emission Inventory

(2) FuelOil and Oil Heat; Intermediate Boiler Study, Walden

(3) Walden, see Appendix A

(4) Independent Gas Association of America; Yankee Oilman

variables for regions as large as states, reduced the significance of the more sophisticated methods. It was, therefore, decided to use the EPA factor to arrive at statewide residential distillate oil used for spaceheating. Distillate oil used for nonspaceheating was calculated by multiplying the number of housing units using oil for hot water heating [4] by 250 gallons per year [1].

This calculation is used only when selected counties are being processed. When all counties within a state are processed, the more refined residential distillate oil figures for each county are summarized to provide the state figure.

2. <u>County Fuel Oil</u>

Using residential gas data by municipalities provided by various gas companies throughout the country, Walden performed a more detailed stepwise regression analysis, resulting in the relationships shown below.

$$\text{gas use (Mcfs)} = 0.01288 \times \text{degree-days} + 30.41 \times \text{average rooms per housing unit} - 79.54$$

The multiple correlation coefficient (R^2) was 0.67 and the standard error was 20% of the mean. For more details on this regression analysis, the reader is referred to Appendix A.

Assuming that gas and fuel oil consumed for residential use are utilized in approximately the same fashion, Walden converted this formula to produce results in gallon of oil consumed and applied it to the housing units using oil in each county [4] to estimate the distillate oil used by these units.

3. Additional Data

For census years, the number of housing units using oil for spaceheating and nonspaceheating purposes are easily available [4]. In order to estimate the number of housing units using oil for spaceheating in each state in the intermediate years, the following method is used:

(1) The number of oil burners installed in new homes [5] during the time-span between the year of concern and the census year is expressed as a percentage of the number of oil burners in use at the end of the census year (factor 1).

(2) The number of conversions to oil burners [5] minus the oil burners lost to other fuels [5] during the time-span between the year of concern and the census year is expressed as a percentage of the number of oil burners in use at the end of the census year (factor 2).

(3) Housing units using oil in year t = housing units using oil in the census year prior to t + [(factor 1 + factor 2) x housing units using oil in the census year prior to t].

Other possible sources to update the census data on housing units were considered,but both the Construction Reports [6] and data published by the F. W. Dodge Co. [7] were found to be incomplete for residential units.

The same state percentage change is assumed for housing units using oil in all counties within that state. This is only an estimate, and the error factor is estimated to be within 2 or 3 percent.

B. COMMERCIAL

1. State Fuel Oil

The commercial category is an extremely complex one, and in the county-wide allocation methodology, Walden has attempted to stratify

the commercial users into a few subcategories which show distinct differences in fuel use patterns.

On a statewide level, the fuel oil figures include all oil burned in stationary sources which is not included under the residential, industrial, or power plant categories. This means:

Commercial distillate oil = all distillate oil categories, except power plants - residential distillate oil (see page 3-3) - industrial distillate oil (see page 3-10).

Commercial residual oil = all residual oil categories, except power plants - industrial residual oil (see page 3-11).

2. County Fuel Oil

The logic of the methodology to determine commercial fuel oil consumed on a county-wide basis is that of separating out the major categories which consume fuel oil in a special way, and distributing the remaining fuel oil by means of adjusted county commercial employment figures [9].

For this purpose, Walden performed several linear regressions to determine the correlation between employment and fuel used by the following subcategories:

(1) Hospitals

(2) Schools

(3) Colleges

(4) Laundries

(5) Hotels

The results of these analyses are discussed in detail in Appendix B, and are summarized below in Table 3-2.

TABLE 3-2

REGRESSION RESULTS FOR FUEL OIL
USED BY COMMERCIAL SUBCATEGORIES

Category	Dependent Variable	Independent Variable	R^2	Slope	Intercept
Hospitals	Oil	Employment	0.81	0.715	+208.5
Schools	Oil	Employment	0.58	2.97	+ 76.2
Colleges	Oil	Employment	0.67	0.546	- 40.9
Laundries	Oil	Employment	0.72	0.355	+ 8.4
Hotels	Oil	Rooms*	0.96	1.09	+ 41.5

* Rooms/Employment ratios have been calculated by state (see Appendix B).

Using these relationships it is possible to separate out the fuel oil used by categories in each state based on employment figures [9], once it is known what percentage of the commercial establishments in each state use oil and what grade of oil (distillate or residual) is likely to be used.

In order to determine the fuel choice for the subcategories, it was assumed that the ratio of coal, distillate oil, residual oil and gas for the subcategories in a state would not differ significantly from the fuel use pattern in that state for the commercial category as a whole.

Therefore, Walden collected data by state on commercial coal use [10] and commercial gas use [11]. The results for the selected states are shown in Tables 3-3 and 3-4 for 1970 and 1971, respectively.

The above methods enable us to calculate the distillate and residual oil use for the five categories in each county.

In addition, Walden estimated the distillate and residual oil consumed by housing units in structures of 20 units or more in each county. This was done by assuming that of the units using oil, those in structures of 50 units or more used mostly residual oil [12,13] and all others used distillate oil. Since the 1970 Census of Housing did not provide sufficient data to separate out the units in structures of more than 50 units on a county basis, it was decided to apply the state percentages represented by these units to the county housing unit figures.

The final method for county allocation of commercial fuel oil can thus be reduced to the following steps:

(1) Calculate distillate and residual oil consumed in each county by hospitals, schools, colleges, laundries, hotels and residential units in structures of 20 units or more.

(2) Adjust the statewide distillate and residual oil figures to exclude the oil consumed in all counties by the above categories.

(3) Adjust county and state commercial employment to exclude employment for the first five subcategories.

(4) Distribute the remaining state fuel oil figures by means of the following method:

$$\text{fuel oil consumed in county } i = \frac{\text{adjusted commercial employment in county } i}{\text{adjusted commercial employment in state } I} \times \text{fuel oil consumed in state } I$$

TABLE 3-3

1970 COMMERCIAL COAL, OIL, GAS USE BY STATE

State	Total Btu (Billions)	Coal	% of Total		Gas
			Distillate	Residual	
New Hampshire	7,569	1.3%	31.3%	50.8%	16.5%
Massachusetts	235,601	0.6%	35.2%	52.0%	12.2%
Maryland	50,386	3.5%	16.5%	46.1%	33.9%
Florida	40,641	6.6%	26.4%	18.2%	48.8%
Alabama	33,888	6.4%	7.3%	3.3%	83.0%
Missouri	96,039	3.2%	13.6%	9.2%	74.0%
Texas	140,667	0.1%	16.4%	3.3%	80.3%
South Dakota	12,031	24.5%	9.4%	0.6%	65.5%
Colorado	68,584	11.9%	6.5%	2.3%	79.2%
California	307,991	0.8%	6.7%	24.2%	68.3%
Washington	54,987	3.6%	20.3%	39.7%	36.3%

TABLE 3-4

1971 COMMERCIAL COAL, OIL, GAS USE BY STATE

State	Total Btu (Billions)	% of Total			
		Coal	Distillate	Residual	Gas
New Hampshire	10,215	0.4%	31.6%	53.2%	14.7%
Massachusetts	249,841	0.1%	37.0%	50.0%	12.8%
Maryland	53,178	1.7%	14.4%	48.7%	35.2%
Florida	43,577	3.0%	23.2%	24.2%	49.6%
Alabama	33,249	5.0%	7.8%	2.0%	85.1%
Missouri	90,647	2.0%	14.0%	5.8%	78.1%
Texas	131,627	0.1%	18.9%	2.4%	78.6%
South Dakota	10,899	17.3%	0.0%	0.1%	82.6%
Colorado	70,874	7.8%	7.2%	2.0%	83.0%
California	318,268	0.0%	11.5%	15.5%	73.0%
Washington	54,198	2.5%	21.2%	35.0%	41.3%

(5) Total commercial fuel oil in each county would be the sum of Steps 1 and 4.

Methods suggested by the EPA to allocate commercial fuel oil were previously based on a straightforward distribution by means of employment ratios [1]. This assumed the same ratio of fuel use per employee for all the various types of establishments included in the commercial category. The results of the regression analyses performed for the various subcategories by Walden show that this assumption was incorrect. The methodology used in this project to allocate commercial fuel use to counties is, therefore, considered to be a significant improvement over previous methods.

C. INDUSTRIAL

1. State Fuel Oil

For the years for which industrial fuel oil use is available by state and SIC group from the Census of Manufactures [14], the distillate and residual oil consumed by manufacturers in each state are taken straight out of that publication. Otherwise, the Bureau of Mines data [8] are used to arrive at total industrial fuel oil use by state as shown below:

Industrial distillate oil = [b* x (distillate oil used for heating [8] - residential distillate oil (see page 3-3)] + distillate oil for industrial use [8] + distillate oil for oil company use [8]

---

* $b = \frac{\text{manufacturing employment}}{\text{commercial + manufacturing employment}}$ ' where the commercial category includes wholesale and retail trade, finance, insurance and real estate, and services [10].

Industrial residual oil - [b* x residual oil used for heating [8]] + residual oil for industrial use [8] + residual oil for oil company use [8]

2. County Fuel Oil

The logic of the methodology to determine industrial fuel oil consumed on a county-wide basis is that of adjusting the county employment figures [9] for two-digit SIC groups by a fuel intensity factor, and using these adjusted employment figures to allocate the state fuel oil figures to the appropriate counties.

For those years for which distillate and residual oil data by state and two-digit SIC are available [14], the fuel intensity factors are represented by Barrels/Employment factors, which are developed by state and SIC groups. For the years in which such state data are not published, nationwide fuel intensity factors by two-digit SIC are used to adjust the employment figures. Table 3-5 shows the nationwide fuel intensity ratios which were applied to the 1970, 1971 and 1972 industrial employment figures.

D. HEAVY DUTY VEHICLES

1. State Gasoline and Diesel - HDV

Four heavy-duty vehicle (HDV) truck categories are used:

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* $b = \frac{\text{manufacturing employment}}{\text{commercial + manufacturing employment}}$, where the commercial category includes wholesale and retail trade, finance, insurance and real estate, and services [10].

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TABLE 3-5

NATIONWIDE FUEL INTENSITY RATIOS

SIC	Industry	Fuels Purchased Million $[1]	Employment Thou.[2]	Ratio
20	Food	423.0	1,595	0.27
21	Tobacco	8.5	71	0.12
22	Textile	123.3	948	0.13
23	Apparel	34.6	1,376	0.03
24	Lumber & Wood	147.1	555	0.27
25	Furniture	27.2	446	0.06
26	Paper	462.7	668	0.69
27	Printing	46.6	1,082	0.04
28	Chemicals	772.2	881	0.88
29	Petroleum	384.4	136	2.83
30	Rubber & Plastics	74.0	558	0.13
31	Leather	14.8	304	0.05
32	Stone, Clay, Glass	511.9	592	0.86
33	Primary Metals	1,103.9	1,268	0.87
34	Fab. Metals	174.8	1,354	0.13
35	Machinery, exc. electr.	166.5	1,996	0.08
36	Electr. Equipment	107.3	1,881	0.06
37	Transportation	160.1	1,817	0.09
38	Instruments	28.3	405	0.07
39	Miscellaneous	27.1	422	0.06
19	Ordnance	21.8	343	0.06
	All Manufacturing	4,829.1	19,762	0.24

Sources: (1) 1970 Annual Survey of Manufacturers, Fuels and Electric Energy Used by Industry Groups, U.S. Dept. of Commerce, Washington, D.C.

(2) 1970 County Business Patterns, U.S. Summary, U.S. Dept. of Commerce, Washington, D.C.

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HDV_1 are trucks with gross weights between 6,001 and 10,000 lb.

HDV_2 are trucks with gross weights between 10,001 and 20,000 lb.

HDV_3 are trucks with gross weights between 20,001 and 26,000 lb.

HDV_4 are trucks with gross weights greater than 26,000 lb.

In order to obtain the total motor fuel consumed by all HDV categories in each state, the following calculation is performed:

$$\text{Motor fuel for HDV} = \sum_{i=1}^{i=4} (HDV_i \times \text{average miles}_i/\text{miles per gallon}_i) + \text{commercial buses} \times \text{average gallons per bus} + \text{school buses} \times \text{average gallons per bus}$$

The breakdown of trucks into the four weight categories is available from the Census of Transportation (published every 5 years), or from R. L. Polk in Detroit, Michigan. For 1971, such a stratification was available for 15 states [15]. Walden estimated the correct breakdowns for the remaining states for 1971, based on geographical location. By means of interpolation between the 1967 data [16] and the 1971 data [15], the 1970 breakdown of trucks by weight categories was obtained. For years for which the Census of Transportation data on the R. L. Polk figures are available, such manipulation of the data will be unnecessary.

It is expected that county-wide truck registration data by weight categories will be supplied on a regular basis to the EPA by R. L. Polk of Detroit, Michigan.

Average miles per gallon by weight category are taken from the Census of Transportation and are held constant over the five years following that Census. Upon publication of the new Census of Transportation, these averages must be updated.

Miles per gallon figures by weight category were derived from Road User and Property Taxes, a tri-annual publication of the Federal Highway Administration. The curve from which this information was derived is shown in Figure 3-1.

Data on buses were obtained from both the Federal Highway Administration [15] and the Automobile Manufacturers Association [17].

Once total motor fuel consumed by HDV's has been calculated for each state, gasoline usage by HDV's is obtained by subtracting total diesel and butane use [15] from the motor fuel figures for each state. Diesel totals for HDV's are estimated annually by the Federal Highway Administration [18].

2. County Gasoline and Diesel - HDV

County use of diesel by HDV's is obtained by using county truck registrations [19] as the apportioning factors to be applied to total diesel used by HDV's in the respective state.

$$\text{Diesel HDV}_{\text{county } i} = \frac{\text{trucks} > 6000 \text{ lb}_i}{\text{trucks} > 6000 \text{ lb}_I} \times \text{diesel HDV}_{\text{state } I}$$

In order to calculate the county use of gasoline for HDV's, the county-by-county R.L. Polk truck registrations by weight categories are used. If these data are not available, county registrations of trucks

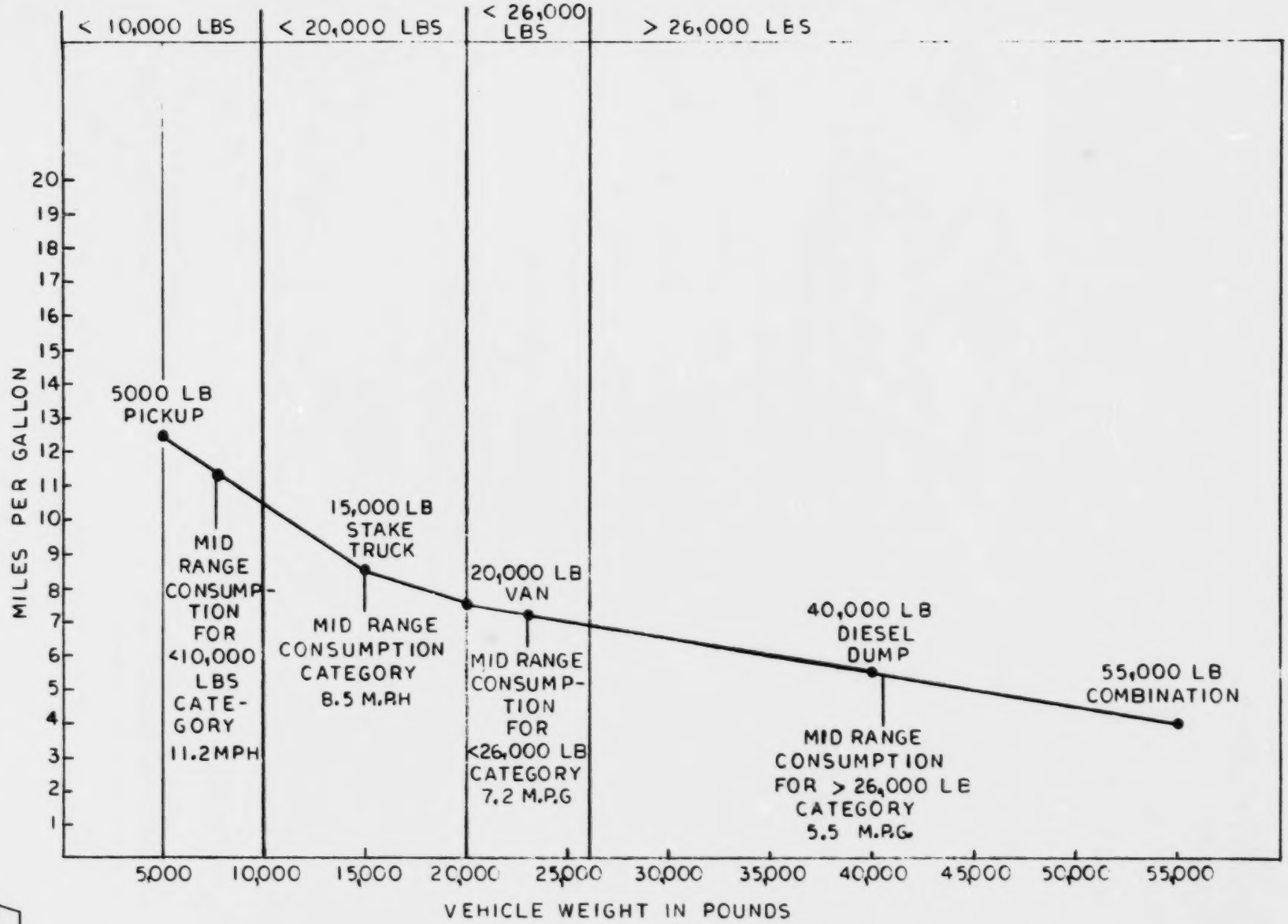

Figure 3-1. Comparison of Various Fuel Consumption Rates for Vehicles of Various Gross Weights.

by weight categories are estimated by assuming that the proportion of registrations in each category is the same for all counties within a state. The remaining calculation is similar to that used to obtain the state totals for this category:

$$(\text{gasoline HDV})_{\text{county } i} = \left[\sum_{j=1}^{j=4} \text{HDV}_j \times \text{avg miles}_{j(I)}/\text{MPG}_{j(I)}\right.$$

$$+ \frac{\text{population (census yr)}_i}{\text{population (census yr)}_I} \times \text{commercial buses} \times 7276 \text{ gallons/bus}$$

$$+ \frac{\text{population (census yr)}_i}{\text{population (census yr)}_I} \times \text{institutional buses} \times 1058 \text{ gallons/bus}$$

$$- \frac{\text{trucks}_i}{\text{trucks}_I} \times (\text{diesel \& butane})_I$$

An alternate method to allocate gasoline and diesel use by heavy-duty vehicles to counties was analyzed. This method was based on a one-time study on truck vehicle miles performed by the Federal Highway Administration. The method consisted of the following steps:

(1) Calculate the vehicle miles traveled on a statewide basis by respectively diesel and gasoline trucks on interstate highways.

(2) Estimate the corresponding county vehicle miles by means of county level interstate highway mileage totals.

(3) Divide the county vehicle miles by the average miles traveled per gallon of fuel to obtain the gasoline and diesel consumed by heavy-duty vehicles on interstate highways in each county.

(4) Estimate the gasoline and diesel used in each county by heavy-duty vehicles on other than interstate highways.

(5) The sum of steps (3) and (4) for respectively gasoline and diesel consumption would be the county-wide figures for the consumption of motor fuels by heavy-duty vehicles.

The method was not used because the procedure was considered too time-consuming and costly, and also because the truck vehicle mile data required would not be available on a yearly basis. For a more detailed description of the analysis of this method, the reader is referred to Appendix D.

E. LIGHT DUTY VEHICLES

1. State Gasoline - LDV

It was assumed that the diesel consumed by LDV's is negligible.* This assumption should probably be re-examined in five years.

Statewide use of gasoline is reported both by the American Petroleum Institute [20] and the Federal Highway Administration [15]. It was found that the FHWA state data were more up-to-date and statistically adjusted, and Walden decided to use these figures instead of those of the API. Statewide use of gasoline by light-duty vehicles is obtained by subtracting the gasoline used by HDV's (see page 3-13) from the total gasoline reported for each state.

2. County Gasoline - LDV

County-wide gasoline figures for LDV's are obtained preferably by using vehicle miles as a distributive factor on the statewide total gasoline figures [21] and subtracting the county use of gasoline by HDV's from the result. For those states for which no county-wide vehicle miles are available, registrations of light-duty vehicles by county [20], adjusted by a rural/urban factor, are to be used.

---

* All on-highway consumption of diesel was assumed to be used by HDV's.

The rural/urban factors were derived from a statistical analysis performed by Walden (see Appendix C). In short, Walden attempted to find significant relationships between miles traveled by cars annually and the degree of ruralness of each county, using data for seven states. The multiple correlation coefficients were found to be too low and the standard errors too high to permit the use of regression curves for this estimation process. The resulting factors are summarized in Table 3-6.

For those states for which no vehicle miles were available, county-wide registrations of automobiles and trucks of less than 6,000 lb weighted by the indexes shown in Table 3-6, were used as the distributive factor to be applied to the statewide gasoline totals. This resulted in total gasoline use by county. By subtracting the previously calculated gasoline used by HDV's, the county-wide gasoline use by LDV's is obtained.

TABLE 3-6

AVERAGE MILES PER VEHICLE BY % RURAL CATEGORIES

State	Entire Sample	Modified Sample	≤ 25%	26-50%	51-75%	76-100%
California	15,152	13,047	10,729	12,202	14,803	16,920
Washington	18,722	17,092	11,940	15,793	15,778	21,855
Kansas	16,155	15,179	10,706	13,622	15,306	17,225
Iowa	15,643	14,604	11,468	12,141	15,501	15,862
Georgia	23,140	20,262	13,185	17,680	19,687	22,461
Maine	15,261	15,261	11,210	15,396	14,876	15,995
Arkansas	18,652	17,932	11,039	15,908	18,144	19,458
Seven State Avg.		16,709	11,217	14,572	17,238	19,261
Indexes		100	67	87	103	115

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18. Special diesel estimates by state provided to Walden by Mr. L.L. Liston of the Federal Highway Administration, Highway Statistics Division, Washington, D.C.

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21. Obtained by contacting all state highway departments in the U.S.

IV. SULFUR CONTENTS AND SEASONAL FLUCTUATIONS

A. SULFUR CONTENTS

The following sources contain information which was used in this project to determine the sulfur content of fuel oils used in the United States:

(1) Actual data from NEDS point source files.

(2) Burner Fuel Oils, Mineral Industry Surveys, Bureau of Mines, Bartlesville, Oklahoma (annual).

(3) Fuel Oils by Sulfur Content, Mineral Industry Surveys, Bureau of Mines, Washington, D.C. (monthly).

(4) Oil Availability by Sulfur Levels, Bureau of Mines, Washington, D.C., August 1971.

(5) Import Supplement to Oil Availability by Sulfur Levels, Bureau of Mines, Washington, D.C., June 1972.

1. Sulfur Content Reported for NEDS Point Sources Using Oil

The NEDS data were summarized by Walden and the results are shown in Tables 4-1 and 4-2 for selected counties. In general, it may be said that the average sulfur contents which could be derived from these data are not applicable to area sources. The distillate oil used by point sources is biased towards grade #4 distillate oil, and the sulfur contents of the residual oil used are also slightly upward biased. It is therefore not recommended to use the sulfur contents derived from these summaries for area sources.

TABLE 4-1

RESIDUAL OIL CONSUMED BY POINT SOURCES
BY SULFUR CONTENT
(thou. gallons)

	< 0.5%	0.5-1%	1-1.5%	1.5-2%	2-2.5%	2.5-3.0%	> 3.0%
Belknap, N.H.	--	--	--	--	2,850	--	--
Franklin, Ma.	--	15,400	--	41,400	164,000	118,000	--
Worcester, Ma.	1,170	7,720	21,900	56,300	161,000	990	--
Baltimore, Md.	--	373,000	166,000	405,000	--	3,270	--
Palm Beach, Fla.	--	--	--	--	--	--	--
St. Louis, Mo.	24	7,830	--	1,300	38	--	--
Minnehaha, S.D.	--	--	25,900	1,060	--	--	--
King, Wa.	--	19,000	1,970,000	--	--	--	--
Galveston, Tx.	--	--	--	--	--	--	--
Jefferson, Ala.	5,840	--	--	--	48	--	--
Boulder, Co.	--	381	2,430	--	--	--	--
Los Angeles, Ca.	--	--	--	--	--	--	--
San Diego, Ca.	--	87,100	121,000	20,700	--	--	--

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TABLE 4-2

PERCENTAGE OF RESIDUAL OIL CONSUMED BY POINT SOURCES BY SULFUR CONTENT

	< 0.5%	0.5-1%	1-1.5%	1.5-2%	2-2.5%	2.5-3.0%	> 3.0%
Belknap, N.H.	--	--	--	--	100	--	--
Franklin, Ma.	--	5	--	12	48	35	--
Worcester, Ma.	negl.	3	9	23	65	negl.	--
Baltimore, Md.	--	39	18	43	--	negl.	--
Palm Beach, Fl.	--	--	--	--	--	--	--
St. Louis, Mo.	negl.	85	--	14	1	--	--
Minnehaha, S.D.	--	--	96	4	--	--	--
King, Wa.	--	1	99	--	--	--	--
Galveston, Tx.	--	--	--	--	--	--	--
Jefferson, Al.	99	--	--	--	1	--	--
Boulder, Co.	--	14	86	--	--	--	--
Los Angeles, Ca.	--	--	--	--	--	--	--
San Diego, Ca.	--	38	53	9	--	--	--

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2. Burner Fuel Oils, MIS, Bureau of Mines

In this publication, which appears yearly, samples of fuels, selected by their manufacturer as typical of that year's production of that specific grade and brand [1] are taken. Walden applied the results shown in these reports to selected counties (see Tables 4-3 and 4-4).

Although the Bureau of Mines sulfur figures are for large regions, lacking the detail required for this project, it seems more accurate to use the average sulfur contents reported by the Bureau of Mines for area source calculations, instead of using the average sulfur content of fuel oil used by the point sources in each county. The Bureau of Mines sample is quite small for #4 and #5 grade fuel oil, but comprises 134, 149 and 109 sample points for respectively #1, #2 and #6 fuel oil in 1970.

It would be extremely useful if the sample size for this survey were significantly increased, enabling summaries of sulfur contents of burner fuel oils by smaller regions. This would provide the EPA with better sulfur content data to be used in area source emission calculations.

3. Fuel Oils by Sulfur Content, MIS, Bureau of Mines

In this monthly publication, sulfur content data are shown for #4 fuel oil and residual oil imported into the United States. The December issue usually contains a summary of the type shown in Tables 4-5 and 4-6. The problem with these data is that the sulfur content applies to the fuel as imported into the state shown. It has been found that the

TABLE 4-3

SULFUR CONTENT ANALYSIS BASED ON BUREAU OF MINES DATA[1]
(1970)

API Region	County	Average Sulfur Contents by Fuel Oil Type					
		#1	#2	#4	#5 (light)	#5 (heavy)	#6
Eastern	Belknap, N.H. Franklin, Ma. Worcester, Ma. Baltimore, Md.	0.064	0.210	0.66	0.78	0.96	1.36
Southern	Palm Beach, Fl. Galveston, Tx. Jefferson, Al.	0.042	0.172	0.47*	1.66*	n.a.	1.73
Central	St. Louis, Mo. Minnehaha, S.D.	0.082	0.281	0.68	1.83	1.40	1.77
Rocky Mountain	Boulder, Co.	0.111	0.316	1.37	n.a.	2.12	2.21
Western	King, Wa. Los Angeles, Ca. San Diego, Ca.	0.091	0.213	n.a.	n.a.	1.55	1.73

(1) Mineral Industry Surveys, Burner Fuel Oils, 1971, Bureau of Mines, Washington, D.C.

*Sample consists of 1

n.a. - not available

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TABLE 4-4

SULFUR CONTENT ANALYSIS BASED ON BUREAU OF MINES DATA[1]
(1971)

API Region	County	Average Sulfur Contents by Fuel Oil Type					
		#1	#2	#4	#5 (light)	#5 (heavy)	#6
Eastern	Belknap, N.H. Franklin, Ma. Worcester, Ma. Baltimore, Md.	0.071	0.210	0.68	0.82	0.96	1.22
Southern	Palm Beach, Fl. Galveston, Tx. Jefferson, Al.	0.042	0.187	0.59*	n.a.	3.22*	1.90
Central	St. Louis, Mo. Minnehaha, S.D.	0.082	0.270	0.64	1.78	1.42	1.72
Rocky Mountain	Boulder, Co.	0.090	0.318	n.a.	3.6*	1.61	1.81
Western	King, Wa. Los Angeles, Ca. San Diego, Ca.	0.079	0.212	0.75*	n.a.	1.43	1.70

(1) Mineral Industry Surveys, Burner Fuel Oils, 1971, Bureau of Mines, Washington, D.C.

*Sample consists of 1

n.a. - not available

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TABLE 4-5

IMPORTS OF #4 FUEL OIL BY PERCENT SULFUR CONTENT
BY STATES: JAN-DEC 1971 (thou barrels)

DISTRICT STATE	PERCENT SULFUR CONTENT				TOTAL
	0-.50	.51-1.00	1.01-2.00	OVER 2.00	
P.A.D. I					
NEW ENGLAND					
CONNECTICUT	-	414	765	-	1178
MAINE	55	-	-	-	55
MASSACHUSETTS	279	1146	-	-	1425
RHODE ISLAND	-	155	-	-	155
TOTAL.....	334	1715	765	-	2814
CENTRAL ATLANTIC					
DELAWARE	-	128	-	-	128
MARYLAND	56	466	-	-	522
NEW JERSEY	1360	756	-	-	2116
NEW YORK	8440	5522	1482	67	15511
PENNSYLVANIA	967	569	2	245	1782
TOTAL.....	10922	7440	1484	312	20059
LOWER ATLANTIC					
FLORIDA	-	278	-	-	278
GEORGIA	-	-	13	789	802
NORTH CAROLINA	-	-	-	20	20
VIRGINIA	-	-	409	-	409
TOTAL.....	-	278	422	809	1509
U.S.. TOTAL.....	11157	9433	2670	1121	24381

SOURCE: OFFICE OF OIL AND GAS.
NOTE..DATA MAY NOT ADD TO TOTALS SHOWN BECAUSE OF INDEPENDENT ROUNDING

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TABLE 4-6

IMPORTS OF RESIDUAL FUEL OIL BY PERCENT SULFUR CONTENT BY STATES: JAN-DEC 1971 (thou barrels)

DISTRICT STATE	PERCENT SULFUR CONTENT 0-.50	.51-1.00	1.01-2.00	OVER 2.00	TOTAL
P.A.D. I					
NEW ENGLAND					
CONNECTICUT	872	10545	3865	17297	32417
MAINE	-	-	2700	14259	16970
MASSACHUSETTS	3293	16081	11759	19657	52790
NEW HAMPSHIRE	-	110	3493	2757	6360
RHODE ISLAND	50	1758	3558	3833	9219
TOTAL.....	4214	30544	25385	57813	118256
CENTRAL ATLANTIC					
DELAWARE	29	-	315	346	690
MARYLAND	354	27547	6682	3565	38149
NEW JERSEY	27241	6023	1939	1419	36622
NEW YORK	60328	57485	12862	35967	166642
PENNSYLVANIA	16589	27307	4627	7007	55530
TOTAL.....	104540	118361	26426	48305	297632
LOWER ATLANTIC					
FLORIDA	274	14241	17296	28528	60339
GEORGIA	-	-	397	5204	5601
NORTH CAROLINA	-	-	2350	5078	7428
SOUTH CAROLINA	-	15	2179	7335	9529
VIRGINIA	-	-	2797	29192	31989
TOTAL.....	274	14256	25019	75337	114885
P.A.D. II					
ILLINOIS	-	3145	-	-	3145
MICHIGAN	-	-	62	733	795
MINNESOTA	-	-	-	12	12
TOTAL.....	-	3145	62	745	3953
P.A.D. V					
CALIFORNIA	-	-	66	-	66
HAWAII	-	-	246	416	663
WASHINGTON	-	-	21	-	21
TOTAL.....	-	-	334	416	750
U.S.. TOTAL.....	109328	166606	77225	182615	535776

SOURCE: OFFICE OF OIL AND GAS.
NOTE..DATA MAY NOT ADD TO TOTALS SHOWN BECAUSE OF INDEPENDENT ROUNDING
INCLUDES 171,000 BARRELS OF CRUDE OIL FOR DIRECT BURNING AS FUEL.

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various fuel oils are frequently blended, sometimes by the dealers and sometimes by the industrial establishment consuming the fuel, in order to comply with the sulfur in fuel regulations for the particular region. Thus, a fuel oil dealer in Massachusetts may sell residual oil with a sulfur content of 1% as imported to customers outside the 13 cities and towns around Boston, but may blend this residual oil with fuel oil of a lower sulfur content for his Boston customers in order to comply with the sulfur restrictions for that area.

4. Oil Availability by Sulfur Levels, Bureau of Mines, 1971

This report essentially surveys the data discussed under 2. and 3. in great detail for earlier years.

5. Import Supplement to Oil Availability by Sulfur Levels, Bureau of Mines, 1972

This report supplements the discussion in the 1971 report.

In addition data from state and local air pollution agencies indicate that most do not collect sulfur content data. As estimated in Figure 4-1, fewer than half of the agencies collects sulfur content information and of those that do, only about 20% compile the data for reference purposes. Most sulfur content information was obtained from samples taken at industrial plants and bulk oil terminals or from fuel oil dealers. The forms used to record such data varied widely, from permit application forms to forms designed by the air pollution agencies. The majority of agencies

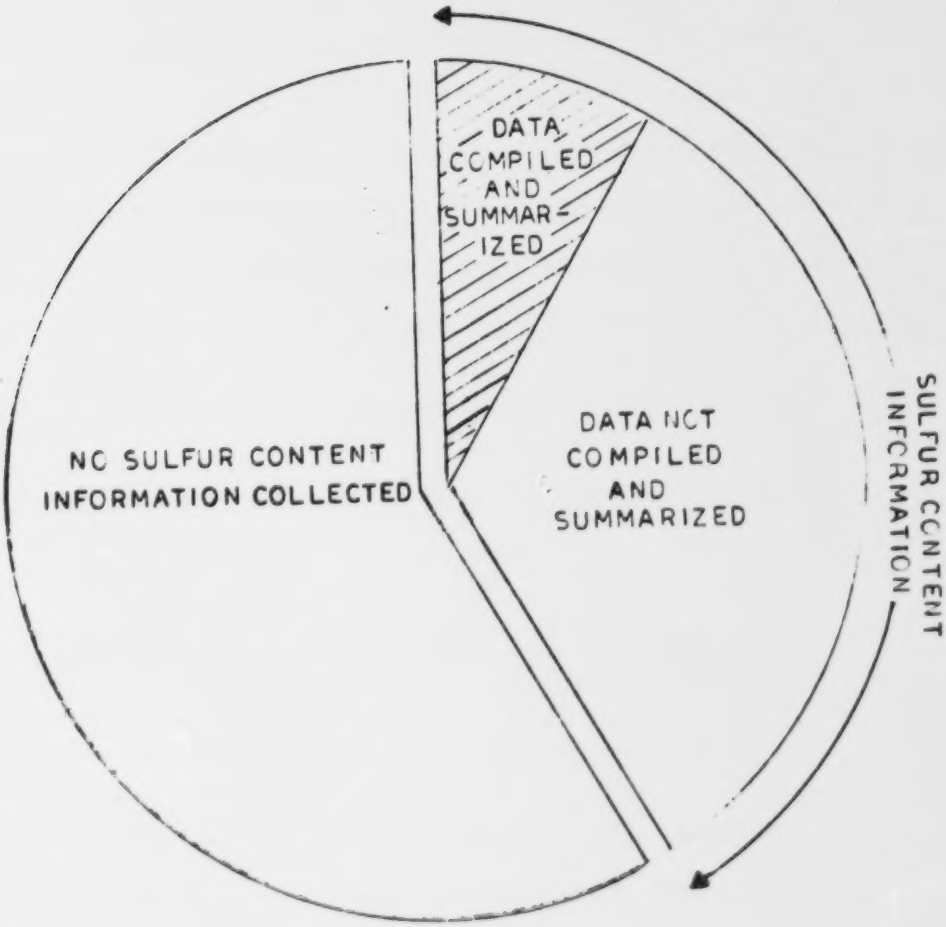

Figure 4-1. Summary of Availability of Sulfur Content Data from Local and State Air Pollution Agencies

collecting data on sulfur contents of distillate and residual oils take fewer than 5 samples per year.

A listing of agencies which may have summaries on file of sulfur content data is shown in Table 4-7.

In general, it is recommended that the data of the Bureau of Mines publications [1,2] be used to arrive at average sulfur contents for area source emission calculations. These average sulfur contents should then be checked against the sulfur in fuel regulations in the various areas. Where the data are available (see Table 4-7), it is recommended that sulfur content information available from local agencies be considered in addition to the above sources.

B. SEASONAL FLUCTUATIONS

Residential and commercial use of fuels is highly dependent on degree-days, since most of the fuel is consumed for spaceheating purposes. Degree-days have been used here to estimate the percentages of fuel oil burned by residential and commercial users in each quarter [3]. Estimates of the seasonal fluctuations in residential and commercial fuel use are shown in Tables 4-8 and 4-9 for selected counties for 1970 and 1971.

To get a clear picture of the seasonal fluctuations of industrial fuel oil use, a summary was made of seasonal information available for point sources on the NEDS files. The results of this summary are shown in Table 4-10 by industry groups. It is suggested that such a summary be made after each annual updating of the NEDS point source file.

TABLE 4-7

AGENCIES COMPILING SULFUR CONTENT DATA

1. Dept. of Health, Town Hall Annex, Greenwich, Ct. 06830
2. D.A.P.C., Prince George's County Health Dept., Cheverly, Md. 20785
3. Dept. of Air Quality Control, 4525 Indianapolis Blvd., E. Chicago, In.
4. State of Maryland Dept. of Health & Mental Hygiene, Environmental Health Administration, 610 N. Howard St., Baltimore, Md. 21201
5. County of Sacramento Health Agency, Environmental Health Services, 6730 Folsom Blvd., Sacramento, Ca. 95819
6. Anne Arundel County Dept. of Health, Air Quality Control Sect., 3 Broad Creek Pkwy., Annapolis, Md. 21401
7. Manatee County Health Dept., 202 Sixth Ave., East, Bradenton, Fl. 33506
8. Puget Sound Air Pollution Control Agency, 410 W. Harrison St., Seattle, Wa. 98119
9. Environmental Improvement Agency, Pera Building College & W. Manhattan St., Santa Fe, N.M. 87501
10. Utah State Division of Health, 44 Medical Drive, Salt Lake City, Ut. 84113

TABLE 4-8

SEASONAL FLUCTUATIONS OF FUEL USE FOR RESIDENTIAL AND COMMERCIAL SPACEHEATING - 1970 (BASED ON DEGREE-DAYS)

County	Jan.-March	April-June	July-Sept.	Oct.-Dec.
Belknap, N.H.	51%	12%	3%	34%
Franklin, Ma.	51%	13%	3%	33%
Worcester, Ma.	51%	13%	3%	33%
Baltimore, Md.	59%	9%	0%	32%
Palm Beach, Fl.	76%	0%	0%	24%
St. Louis, Mo.	57%	7%	0%	36%
Minnehaha, S.D.	51%	10%	3%	36%
King, Wa.	37%	20%	6%	37%
Galveston, Tx.	72%	2%	0%	26%
Jefferson, Al.	59%	4%	0%	37%
Boulder, Co.	45%	15%	3%	37%
Los Angeles, Ca.	48%	17%	0%	34%
San Diego, Ca.	45%	19%	0%	36%

TABLE 4-9

SEASONAL FLUCTUATIONS OF FUEL USE FOR RESIDENTIAL AND COMMERCIAL SPACEHEATING - 1971 (BASED ON DEGREE-DAYS)

County	Jan.-March	April-June	July-Sept.	Oct.-Dec.
Belknap, N.H.	50%	14%	3%	33%
Franklin, Ma.	52%	15%	2%	31%
Worcester, Ma.	52%	15%	2%	31%
Baltimore, Md.	58%	11%	1%	30%
Palm Beach, Fl.	94%	6%	0%	0%
St. Louis, Mo.	59%	9%	1%	30%
Minnehaha, S.D.	51%	10%	3%	36%
King, Wa.	40%	20%	6%	34%
Galveston, Tx.	71%	3%	0%	26%
Jefferson, Al.	63%	9%	0%	28%
Boulder, Co.	41%	16%	5%	37%
Los Angeles, Ca.	42%	15%	0%	43%
San Diego, Ca.	49%	17%	0%	34%

TABLE 4-10

SUMMARY OF SEASONAL FLUCTUATIONS OF RESIDUAL OIL
USED BY POINT SOURCES
(Percentages)

SIC	Industry Group	Winter	Spring	Summer	Fall
19	Ordnance	36	22	14	28
20	Food	29	29	21	21
21	Tobacco	25	25	25	25
22	Textiles	28	25	22	25
23	Apparel	37	25	13	25
24	Lumber & Wood	25	25	25	25
25	Furniture	31	25	19	25
26	Paper	26	25	24	25
27	Printing	38	23	13	26
28	Chemicals	27	25	23	25
29	Petroleum	25	25	25	25
30	Rubber & Plastics	30	25	20	25
31	Leather	32	25	18	25
32	Stone, Clay, Glass	25	25	24	25
33	Primary Metals	26	28	24	22
34	Fab. Metals	28	25	22	25
35	Machinery exc. electr.	29	25	20	25
36	Electr. Equip.	35	24	17	24
37	Transportation	40	16	11	33
38	Instruments	27	25	23	25
39	Miscellaneous	27	25	14	24

The seasonal fluctuations of gasoline and diesel consumption are very slight when lumped together by quarters for the various states. Whether the quarters are taken to be January through March, April through June, etc., or December through February, March through May, etc., seems to make little difference. Month by month fluctuations are slightly more significant and are available from the Federal Highway Administration by state [4]. July and August usually show the highest motor fuel usage in most states.

REFERENCES - SECTION IV

1. Burner Fuel Oils, Mineral Industry Surveys, Bureau of Mines, Bartlesville, Oklahoma.

2. Fuel Oils by Sulfur Content, Mineral Industry Surveys, Bureau of Mines, Washington, D.C.

3. Climatological Data, U.S. Dept. of Commerce, National Oceanographic and Atmospheric Administration, Asheville, North Carolina.

4. Highway Statistics, Federal Highway Administration, Washington, D.C.

V. COMPUTER PROCESSING

A. INTRODUCTION

In order to facilitate the annual calculations required to obtain fuel oil consumption and seasonal fluctuations figures for the more than 3,000 counties, the methods described in the previous chapters were programmed in Fortran IV for use on an IBM System 360.

Card input forms for three separate card files were designed to be used in these programs. These files contain:

- data required to allocate fuel oil consumption by county;
- data required to determine seasonal flucuations;
- point source employment data.

The computer processing flow is indicated in Figure 5-1 and summarized below.

1. The input card-files are transferred onto tape by means means of an IBM program which generates card-image tapes for each file.

2. Each tape goes through a sort/merge procedure which outputs a magnetic tape with card-image data sorted in the right sequence.

3. A tape containing all NEDS point source data for point sources using oil and the point source employment data file are used

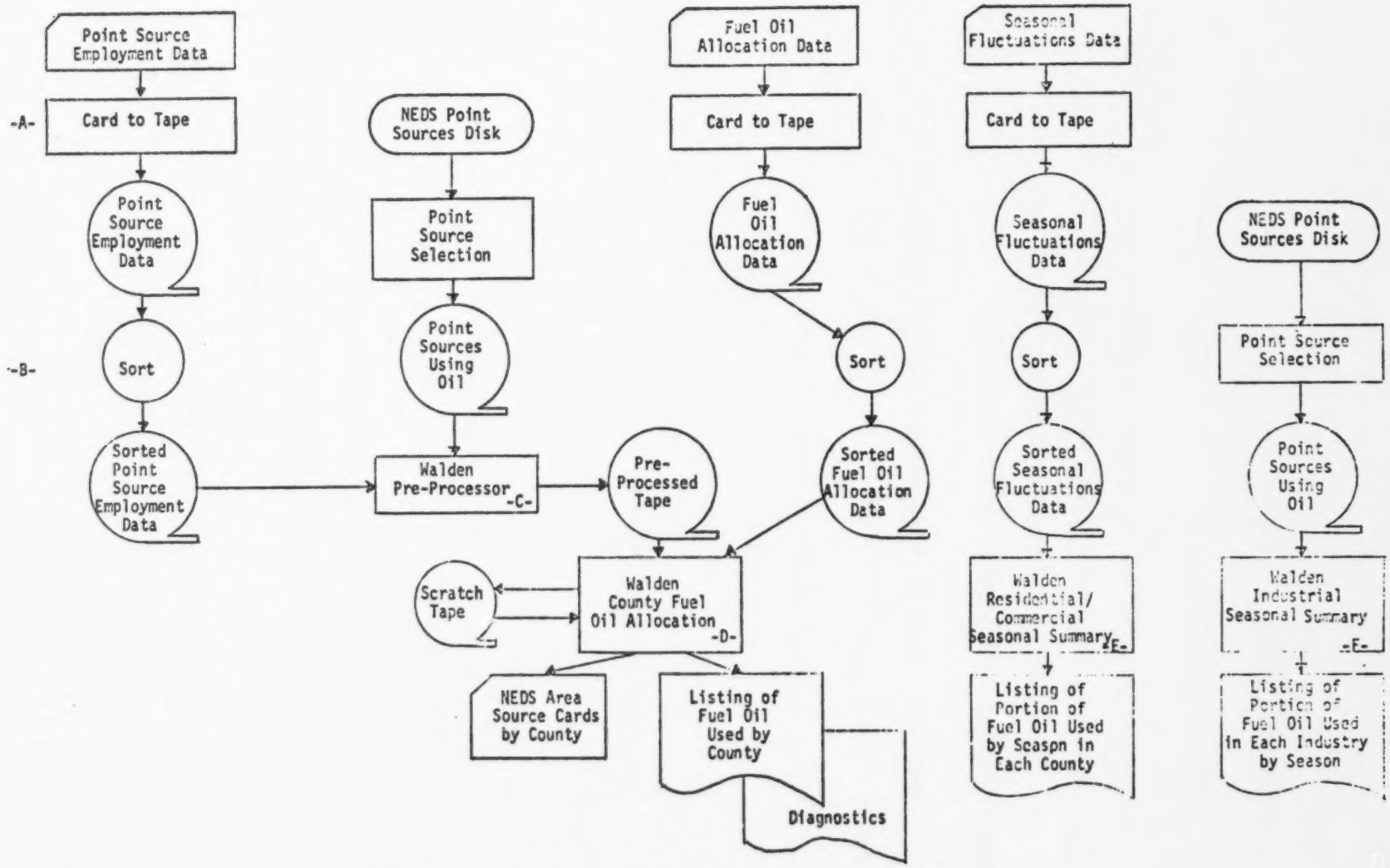

Figure 5-1 Computer Processing Phase for Fuel Oil Allocation Program

as input to the WALDEN PREPROCESSOR PROGRAM. This program prepares an output tape with all the point source data which are relevant for the following County Allocation Program.

4. The sorted fuel oil allocation data file and the pre-processed tape from the previous step are input to the WALDEN COUNTY FUEL OIL ALLOCATION PROGRAM. This program allocates fuel oil, gasoline and diesel by user categories to the counties of the United States. The results are printed and also punched out in the NEDS area source format. In addition, a diagnostic listing is provided, indicating areas that should be checked, e.g., if the industrial use of distillate oil by point sources is larger than the total industrial distillate oil use, the distillate oil used by industrial area sources for that region will automatically be set to zero and reported. This diagnostic listing should be analyzed to ensure that the problem did not arise due to coding or keypunching errors.

5. The seasonal fluctuations data file is input to the WALDEN RESIDENTIAL/COMMERCIAL SEASONAL SUMMARY PROGRAM, which produces a county by county breakdown of the percentage of residential and commercial fuel oil consumed in each quarter.

6. A special card-image tape can be produced from the NEDS disk files containing all point sources using fuel oil. This tape is input to the WALDEN INDUSTRIAL SEASONAL SUMMARY PROGRAM, which produces a statewide breakdown of the percentages of fuel oil consumed in each quarter, by 2-digit SIC. A national summary by 2-digit SIC is also provided.

B. PROGRAM DESCRIPTIONS

Below a short description is given of each of the four programs containing the methodologies described in the previous chapters.

1. The WALDEN PREPROCESSOR program

Input: - point source fuel oil tape, containing data on all point sources which consume fuel oil

- point source employment tape, containing employment data for all point sources which consume fuel oil. This tape is in variable NEDS card-image layout (see page 5-5).

Output: - preprocessed point source tape containing fuel oil and employment data summarized by county and various commercial and industrial subcategories.

Program function: - The WALDEN PREPROCESSOR Combines all the point source information required for the main fuel oil allocation program by county on a single tape. This tape contains summarized county figures for manufacturing fuel oil use and employment by 2-digit SIC group, and commercial oil use and employment by the various subcategories, i.e., hospitals, hotels, schools, colleges, and laundries, as well as the total categories wholesale trade; retail trade; finance, insurance, and real estate; and services.

2. The WALDEN COUNTY FUEL OIL ALLOCATION program

Input: - preprocessed point source tape

- fuel oil allocation data tape: this is a sorted card-image tape (see pages 5-10 to 5-14 for card layouts)

Output: - printed listing of fuel oil used by county

- diagnostic listing

- NEDS area source cards by county (see Figure 5-2 for card layouts*)

*Only the darkened fields in Figure 5-2 contain data in the punched out cards.

FORMAT OF POINT SOURCE EMPLOYMENT DATA

State	County	AQCR	Plant I.D. Number		Duns Number	Plant* Employment		SIC* GP.		IDENTIFICATION Action	IDENTIFICATION Card Sequ. No.	IDENTIFICATION Card No.

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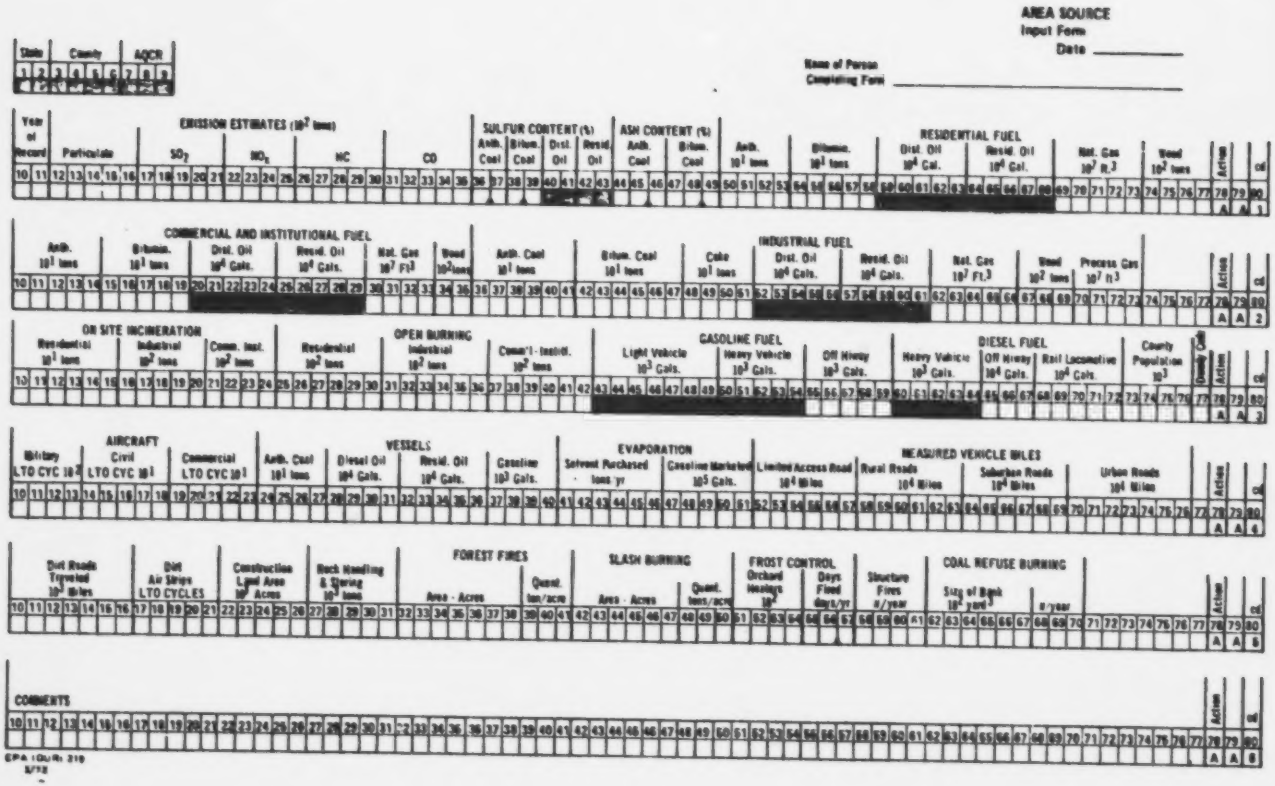

Figure 5-2. Area Source Coding Form

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Program function: - The WALDEN COUNTY FUEL OIL ALLOCATION program contains all the methods described in Chapter III to allocate by county the fuel oil consumed by residential, commercial and industrial area sources, and the gasoline and diesel consumed by light-duty and heavy-duty vehicles. Since the program is intended to apply to area sources only, point source fuel oil and employment data are subtracted from respectively the state fuel oil totals and the state and county employment totals. Figure 5-3 shows the approximate program flow. A more detailed description of the program, with clear indications concerning the various program steps is available in the program documentation provided to EPA-NADB.

3. The WALDEN RESIDENTIAL/COMMERCIAL SEASONAL SUMMARY program

Input: - seasonal fluctuations data tape: this is a sorted card-image tape (see page 5-15 for card layout)

Output: - printed listing of the percentages of annual residential and commercial fuel oil consumed during each quarter of the year by county

Program function: - This program merely summarizes the monthly degree-day data on the input by quarters for each county

4. The WALDEN INDUSTRIAL SEASONAL SUMMARY program

Input: - card-image NEDS point source tape (see Figure 5-4 for card layout)

Output: - printed listing of the fuel oil consumed in each season of the year by industrial point sources by county and 2-digit SIC.

Program function: - The program summarizes the point source fuel oil consumption data by county and by season for each industry group and provides a national summary by industry group at the end.

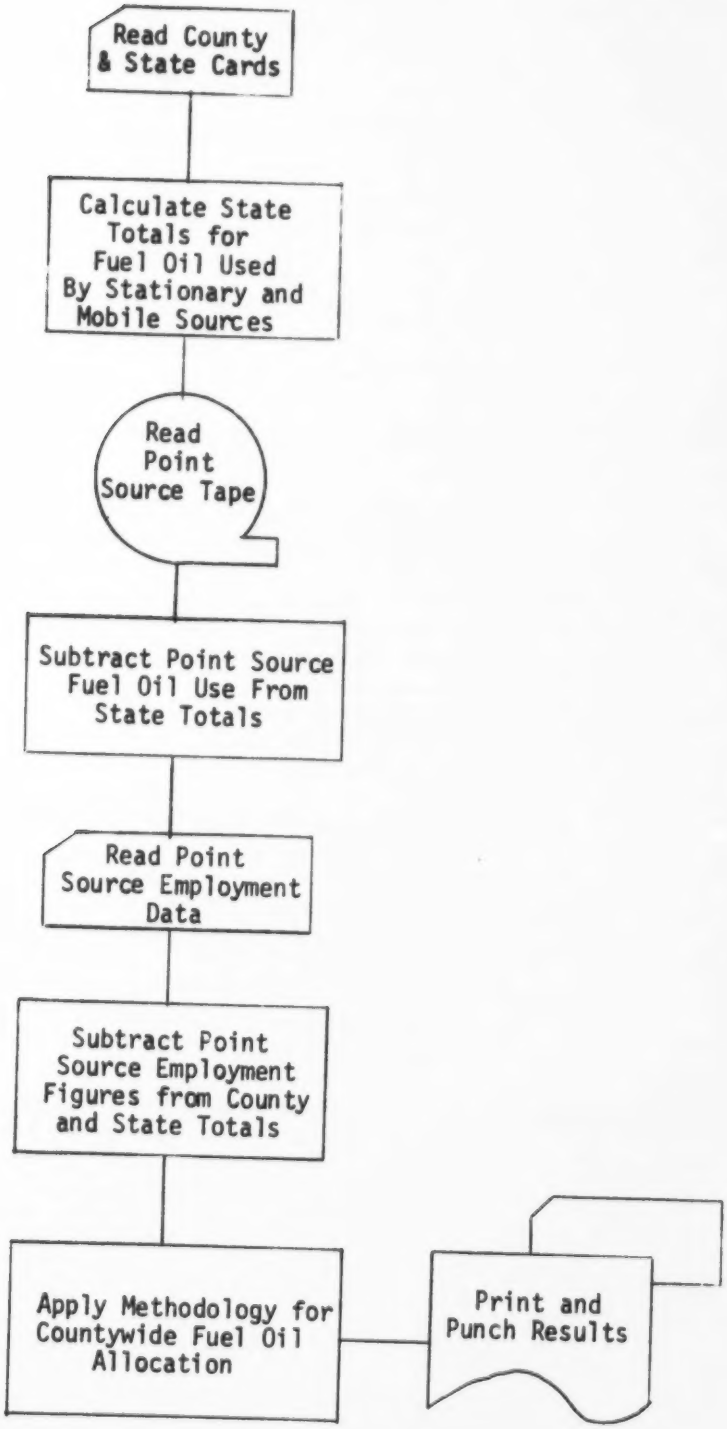

Figure 5-3. Flow Chart of Countywide Fuel Oil Allocation Program

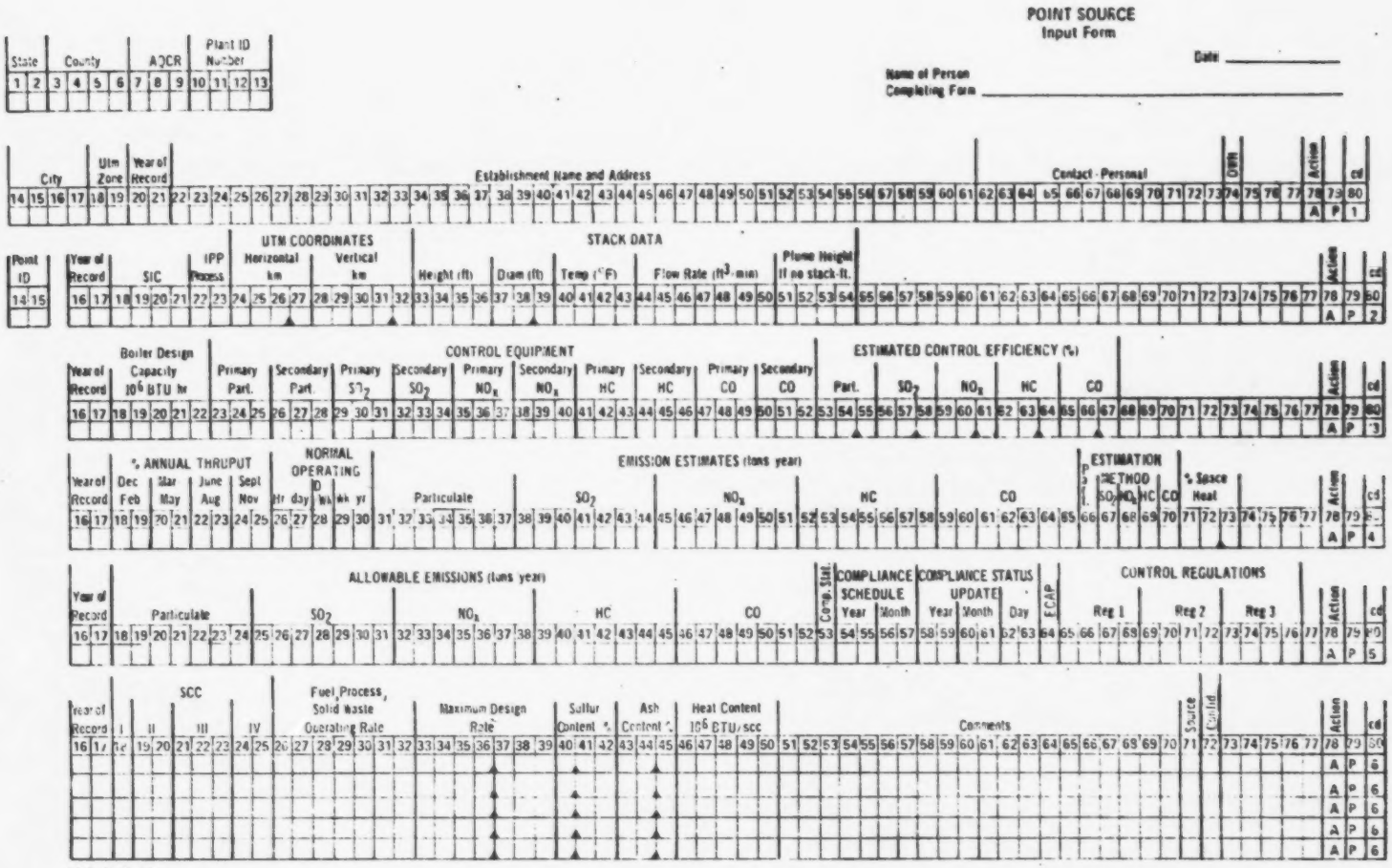

Figure 5-4. NEDS Point source coding form.

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BUREAU OF MINES DATA STATE CARD TYPE 1

State	Year of record	Heating Oils				Industrial		Oil Company		Military		
		#1	#2	#4	Residual	Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	
												1
												1
												1

CENSUS OF MANUFACTURES FUEL OIL DATA STATE CARD TYPE 2

State	Year of record	SIC 20		SIC 21		SIC 22		SIC 23		SIC 24		SIC 25		SIC 26		SIC 27		
		Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	
																		2
																		2
																		2

CENSUS OF MANUFACTURES FUEL OIL DATA STATE CARD TYPE 3

State	Year of record	SIC 28		SIC 29		SIC 30		SIC 31		SIC 32		SIC 33		SIC 34		SIC 35		
		Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	
																		3
																		3
																		3

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CENSUS OF MANUFACTURES FUEL OIL DATA STATE CARD TYPE 4

State	Year of record	SIC 36		SIC 37		SIC 38		SIC 19/39		
		Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	Dist.	Resid.	
										4
										4
										4

MOBILE SOURCE FUEL DATA STATE CARD TYPE 5

State	Year of record	SALES			
		Diesel & Butane	Diesel	Gasoline	
					5
					5
					5

RESIDENTIAL DATA STATE CARD TYPE 6

State	Year of record	HOUSING UNITS - CENSUS YEAR				Percent Change Since Census	Annual Degree Days	Population (Census Year)	Census Year Housing Units In Structures Greater than 50	
		Total	In Structure Greater than 20	Using Oil for Spaceheating	Using Oil for Hot Water					
										6
										6
										6

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COMMERCIAL EMPLOYMENT DATA STATE CARD TYPE 7

State	Year of Record	Wholesale	Retail	Finance Insurance & Real Estate	Services	Hospitals	Hotels	Colleges	Schools	Laundries	Commercial		
											Coal	Gas	
													7
													7
													7

MANUFACTURING EMPLOYMENT DATA STATE CARD TYPE 8

State	Year of Record	SIC 20	SIC 21	SIC 22	SIC 23	SIC 24	SIC 25	SIC 26	SIC 27	SIC 28	SIC 29	SIC 30	SIC 31	
														8
														8
														8

MANUFACTURING EMPLOYMENT DATA STATE CARD TYPE 9

State	Year of Record	SIC 32	SIC 33	SIC 34	SIC 35	SIC 36	SIC 37	SIC 38	SIC 19/39	Total	
											9
											9
											9

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MOBILE SOURCE DATA STATE CARD TYPE 10

State	Year of record	REGISTRATIONS						Average Miles Driven by Trucks				# of Comm. & Munic. Buses	# of School & Instit. Buses	Vehicle Miles	% Rural (state)
		Automobile	Trucks less than 6000 lbs	Trucks 6001 to 10,000 lb	Trucks 10,001 to 20,000 lb	Trucks 20,001 to 26,000 lb	Trucks more than 26,000 lb.	6001 to 10000	10001 to 20000	20001 to 26000	more than 26000				
															10
															10
															10

RESIDENTIAL DATA COUNTY CARD TYPE 11

State	County	AQCR	Year of record	HOUSING UNITS - CENSUS YEAR				Percent Change Since Census	Annual Degree Days	Avg. Rooms Per Unit	% SULFUR			
				Total	In structures Greater than 20	Using Oil for Spaceheating	Using Oil for Hot Water				Dist. Oil	Resid.	Population	
														11
														11

COMMERCIAL EMPLOYMENT DATA COUNTY CARD TYPE 12

State	County	AQCR	Year of record	Wholesale	Retail	Finance, Insurance & Real Estate	Services	Hospitals	Hotels	Colleges	Schools	Laundries	
													12
													12
													12

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MANUFACTURING EMPLOYMENT DATA COUNTY CARD TYPE 13

State	County	AQCR	Year of record	SIC 20	SIC 21	SIC 22	SIC 23	SIC 24	SIC 25	SIC 26	SIC 27	SIC 28	SIC 29	SIC 30	
															13
															13
															13

MANUFACTURING EMPLOYMENT DATA COUNTY CARD TYPE 14

State	County	AQCR	Year of record	SIC 31	SIC 32	SIC 33	SIC 34	SIC 35	SIC 36	SIC 37	SIC 38	SIC 19/39	Total	
														14
														14
														14

MOBILE SOURCE DATA COUNTY CARD TYPE 15

State	County	AQCR	Year of record	Automotive	Trucks <6000 lbs	Trucks 6,001 to 10,000 lb.	Trucks 10,001 to 20,000 lb.	Trucks 20,001 to 26,000 lb	Trucks more than 26,000 lb.	Vehicle Miles	% Rural	COMMENTS	
													15
													15
													15

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FORMAT OF SEASONAL FLUCTUATIONS DATA - CARD TYPE 16

(degree-days)

St.	County	AQCR	yr. of rec		July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	weather station code	C.T.
1	2 3 4 5	6	7 8 9	10 11	12 13 14 15	16 17 18 19	20 21 22 23	24 25 26 27	28 29 30 31	32 33 34 35	36 37 38 39	40 41 42 43	44 45 46 47	48 49 50 51	52 53 54 55	56 57 58 59	60 61 62 63	64 65 66 67	68 69 70 71	72 73 74 75	76 77 78 79	80
																						16
																						16
																						16

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VI. RECOMMENDATIONS

A. IMPROVEMENT OF DATA BASE

1. Bureau of Mines Fuel Oil Sales Data (Annual)

The basic source for fuel oil used by stationary sources is the Bureau of Mines annual report showing fuel oil sales by state [1]. This report is published annually in October, with data of the preceeding year. Conversation with Mr. James M. Diehl of the Division of Fossil Fuels, which prepares the report, revealed that the figures are based on the return of a questionnaire (see pages 6-2 and 6-3) which is sent out to oil refiners and fuel oil dealers throughout the country. Approximately 5,000 questionnaires are completed and returned to the Division of Fossil Fuels for further processing. It is estimated that these returns represent about 75% of all distillate oil shipments, and 65% of all residual oil shipments. It is noted that dealers processing less than 10,000 barrels during the year are not required to fill out the questionnaire.

Mr. Diehl informed us that the returns of the questionnaires were high, although response was not obligatory. Questionnaires are not sent out to firms which, in the past, have refused to complete them. Statistical completion of the sample consists mostly of a simple prorating procedure. Based on the above, it is felt:

(1) that the sample is unnecessarily biased towards larger firms,

(2) that the sample may exclude valuable information due to the fact that questionnaires are not mailed out to all refiners and dealers,

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Form 6-1337-A
(November 1967)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON, D.C. 20240

Budget Bureau No. 42-R0030.
Approval expires March 1972.

INDIVIDUAL COMPANY DATA—CONFIDENTIAL

The data furnished in this report will be treated in confidence by the Department of the Interior, except that they may be disclosed to defense agencies.

FUEL OIL AND KEROSINE SHIPMENTS AND INVENTORIES

(

(Please correct if name or address has changed.)

SEE INSTRUCTIONS AND DEFINITIONS ON REVERSE SIDE

I. SHIPMENTS OF FUEL OIL AND KEROSINE DURING THE YEAR BY STATES OF DESTINATION AND BY USES.

(Insert names of States in column headings) →

Type and use	Code 2911-	Barrels	Barrels	Barrels
A. Distillate-type fuel oils:				
1. Direct shipments to consumers by your company for—				
a. Heating:				
(1) Grade #1 for automatic burners	400			
(2) Grade #1 for all other heating	410			
(3) Grade #2	420			
(4) *Grade #4 (_____% heavy _____% light)	440			
b. Industrial use	401			
c. Oil-company use	402			
d. Railroad use	403			
e. Vessel bunkering	404			
f. Military use	405			
g. All other uses	408			
2. Shipments to dealers and resellers	409			
3. Total (Sum of A1 and A2)	411			
B. Residual-type fuel oils:				
1. Direct shipments to consumers by your company for—				
a. Heating:				
(1) *Grade #5 (_____% heavy, _____ light)	550			
(2) Grade #6	560			
b. Industrial use	501			
c. Oil-company use	502			
d. Railroad use	503			
e. Vessel bunkering	504			
f. Military use	505			
g. All other uses	508			
2. Shipments to dealers and resellers	509			
3. Total (Sum of B1 and B2)	511			
C. Kerosine:				
1. Direct shipments to consumers by your company for—				
a. Heating	300			
b. All other uses (excluding jet fuel)	308			
2. Shipments to dealers and resellers	309			
3. Total (Sum of C1 and C2)	311			

II. INVENTORIES OF FUEL OILS AND KEROSINE

(Insert names of States in column headings) →				
Inventories by type	Code 2911	Barrels	Barrels	Barrels
A. Beginning-of-year:				
1. Distillate-type fuel oil (including diesel)	477			
2. Residual-type fuel oil (including heavy diesel)	577			
3. Kerosine (excluding jet fuel)	377			
B. End of year:				
1. Distillate-type fuel oil (including diesel)	488			
2. Residual type fuel oil (including heavy diesel)	588			
3. Kerosine (excluding jet fuel)	388			

If this company changed ownership during the year, please report name and address of present owner, and date sold:

(Name) (Address) (Date sold)

Signature	Official position	Date of report

INSTRUCTIONS FOR COMPLETING THIS FORM

Report all figures in barrels of 42 gallons.

Companies which shipped less than 10,000 barrels (420,000 gallons) of fuel oil and kerosine during the year are not requested to complete this form. Form should be so noted and returned.

This report of the distribution of your shipments should cover all light and heavy fuel oils and kerosine shipped or sold during the year. Include all domestic shipments of these products, whether purchased or of your own manufacture. Report shipments by state of destination and inventories by state of location. Do not include shipments to Puerto Rico, as such information is compiled by the U. S. Department of Commerce. A consolidated report covering all your company's fuel-oil and kerosine shipments and inventories will be acceptable.

Please return one copy of the completed form by April 15. Before submitting the report, please compare it with the previous year's report and verify any inconsistencies such as the addition or elimination of states or products and any sizable differences in quantity data between the two years.

DEFINITIONS

DISTILLATE-TYPE FUEL OIL.—Include ASTM grades 1, 2, and 4 and distillate-type diesel fuel oil.

RESIDUAL-TYPE FUEL OIL.—Include ASTM grades 5 and 6, heavy diesel, Navy special and Bunker C oils used for generation of heat and/or power. Include acid sludge and pitch used for refinery fuel.

KEROSINE.—Include petroleum distillates suitable for use as an illuminant when burned in a wick lamp and kerosine sold for range oil.

HEATING.—Report all fuel oils used for heating purposes. (Indicate the percentage of heavy and light oils contained in grades 4 and 5 fuel oils.)

INDUSTRIAL USE (excluding heating and oil-company uses).—Report under this item all fuel oil shipped to mines, smelters, and plants engaged in producing manufactured products.

OIL-COMPANY USE.—Report all fuel oil, crude oil, or acid sludge used as fuel at your refineries, by your pipelines, or in your field operations. Shipments to other oil companies for field use should be included but exclude shipments for use as refinery charging stocks. Oil used to heat buildings, and operation of marine equipment should be reported under their proper categories.

RAILROAD USE.—Include all fuel oil shipped to railroads, except that used for heating buildings operated by railroads which should be reported as shipments for "Heating".

VESSEL BUNKERING.—Report all fuel oil and diesel oil shipped for ships bunkers and other marine purposes including own-company use. Exclude shipments to the Armed Forces.

MILITARY USE.—Include all fuel oil shipped to the Armed Forces, regardless of use.

ALL OTHER USE.—Include on and off highway, agriculture, utilities and any other use category not covered above.

INVENTORIES.—Report all beginning and ending inventories held by your company for the year indicated on form.

(3) that the statistical extrapolation methods should be refined,

(4) that it would be of interest to other government agencies using these Bureau of Mines reports if the user category "residential" were included in the report.

It is of extreme importance to this study that the actual accuracy of the Bureau of Mines statewide data be determined and, if possible, that the report reflect some of EPA's needs. If this seems to be too difficult a task, in view of the interdepartmental cooperation required, it is recommended that EPA study the possibility of developing a methodology to collect statewide fuel oil consumption data by grade of fuel and user category on an annual basis for its own use.

2. Bureau of Mines, Burner Fuel Oils Data (Annual)

This report is an annual mineral industry survey of the Bureau of Mines, which shows sulfur content data for samples of fuels. The sampled fuel oils are selected by their manufacturer as typical of that year's production of that specific grade and brand.

At present, the sample size is large enough to allow the data to be summarized by five geographic regions. It is recommended that the sample size be significantly enlarged to permit summaries by smaller regions, thus providing more accurate average sulfur contents to be used in emission calculations for area sources.

3. Census of Manufactures, Fuel and Electric Energy Consumed

The Census of Manufactures has published a special report on fuel consumed by industry, showing fuel use by type of fuel by state and two digit SIC. It may become an annual publication, in which case it is likely to be an important source of data for this project. The EPA should indicate its interest in seeing this information produced annually.

4. Highway Administration Data

On a local level, it is recommended that the state Highway Administration agencies be encouraged to collect vehicle mile data by county.

On a national and local level, it is recommended that the Federal Highway Administration attempt to publish yearly truck registrations by weight categories common to all states. It would seem logical to use the categories used by the Census of Transportation.

5. R.L. Polk Data

In the absence of truck registration data by consistent weight categories published by the Federal Highway Administration, it is recommended that the EPA subscribe to annual publications of R.L. Polk of Detroit, Michigan, showing automotive registrations and truck registrations by weight categories on a county by county basis.

6. Point Source Data

It is recommended that point source employment figures be routinely recorded on NEDS variable data forms, to facilitate the preparations required for this project.

B. IMPROVEMENT OF PRESENT STUDY

1. Choice of Fuels

In many cases, especially for commercial users, linear correlations were developed in this study between employment and fuel consumption. The determination of these relationships makes it possible to derive fuel use from county-wide employment data, which are easily available [2]. It is not clear, however, how to determine what percentage of the employees in each county are employed in establishments using fuel oil.

For the purposes of this study, rough estimates were made to arrive at the appropriate fuel oil figures. It is recommended that a study be undertaken to make an inventory of actual regional fuel choices taken by various types of establishments.

2. Linear Correlation Between Commercial Fuel Oil Use and Socio-Economic Data

A preliminary attempt was made during this phase of the study to arrive at linear relationships between fuel oil consumed and employment for various commercial categories. It is felt, however, that it would be

useful to study the commercial category in depth in a separate study, which could result in fuel consumption figures by two digit SIC for the commercial categories in each state.

3. Rural/Urban Driving Patterns

A considerable amount of data was collected on vehicle miles traveled per car in the counties of seven states. These data were correlated with four different variables in a stepwise regression analysis. The results were not significant enough to be finalized and included in this study. Other independent variables should be collected for these counties in order to find the proper relationships which will explain the variability on a county level of average miles traveled per car.

It is recommended that this approach be studied further, in order to arrive at better gasoline consumption data on a county level.

4. Excise Tax Data

It is recommended that the Internal Revenue Service be approached by the EPA to determine if the IRS might be able to cooperate with the EPA in an effort to arrive at gasoline sales data on as detailed a regional level as possible, based on excise tax data. Some such data are available at present, but it seems that the excise tax is not reported by retail outlets.

5. Truck Vehicle-mile Data

It is recommended that the EPA study the results of the alternate method analyzed in Appendix D to allocate motor fuel consumption by heavy-duty vehicles to the various counties. If the time and cost required to implement this method can be justified it is suggested that the EPA approach the Federal Highway Administration with the request to publish the required truck vehicle-mile data on a regular basis.

6. Re-examination of Assumptions

Two basic assumptions should be re-examined within the next five years.

(a) It was assumed here that the amount of diesel consumed by light duty vehicles could be ignored. There may be a change in this pattern in the future and the assumption should be re-examined.

(b) It was assumed here that residential units using oil in structures of 50 units or more would use mostly residual oil as opposed to distillate oil. Because of recent air pollution regulations, larger size buildings are being converted to distillate oil. It is therefore necessary to re-examine this assumption in the near future.

7. Re-examination of Regression Coefficients

Linear relationships were developed in this study based on historical data provided by various gas companies, state highway agencies and the NEDS point source file. In view of the change in consumption

patterns brought about by the energy crisis confronting the country at the time of this writing, it is recommended that the EPA re-examine the coefficients of these linear correlations using 1973 data.

REFERENCES - SECTION VI

1. Fuel Oil Sales, Annual, Bureau of Mines, Washington, D.C.
2. County Business Patterns, U.S. Dept. of Commerce, Washington, D.C.

APPENDIX A

RESIDENTIAL FUEL USE

1. State Fuel Oil

Four different methods were attempted to arrive at the residential use of distillate oil for spaceheating by state:

a. Using EPA's suggested estimate of .18 gallons/unit/degree-day (1) to determine fuel oil consumed for spaceheating requirements.

b. Using the formula:

$$\frac{\text{\# of oil burners x avg size (Btu/hr) x 8760 (hr/yr) x load}}{\text{140,000 (Btu/gallon)}}$$

to determine fuel oil consumed for spaceheating requirements (2).

c. Using a stepwise regression analysis which included the independent variables: degree-days, price of fuel, per capita income, and average number of rooms per housing unit, to determine fuel oil consumed for spaceheating requirements.

d. Using the formula:

$$\frac{\text{\# of oil burners x heat loss x degree-days x use factor}}{\text{140,000 Btu/gallon x Design Range}}$$

to determine fuel oil consumed for spaceheating requirements, where the heat loss was dependent on the average square feet per housing unit (3).

a. EPA METHOD

In order to get an estimate of the residential spaceheating requirements for distillate oil, the following calculations were performed. The number of housing units using oil for spaceheating (1) were recorded for each state. To eliminate units located in large apartment buildings, which may not use distillate oil, the percentage of units in

structures containing 20 units or more was subtracted (1). Using average degree-days for each state (2) and the factor of .18 gallons/unit/degree-day (3), Walden estimated the distillate oil consumed by these residential units for spaceheating. Then we proceeded to calculate the distillate oil consumed for non-spaceheating purposes by state. The number of housing units using oil for hot water heating (1), which is the major use of non-spaceheating fuel oil consumption, was multiplied by 250 gallons (3) for each state. The sum of these estimated spaceheating and non-spaceheating fuel oil consumption figures was then compared to the total #1 and #2 heating oil reported for each state by the Bureau of Mines. The percentages attributable to residential use for each state are shown in Table A-1.

b. OIL BURNER METHOD

Using the formula,

$$\frac{\text{\# of oil burners x avg. size Btu/hr x 8760 (hr/yr) x load}}{\text{140,000 (Btu/gallon)}} \qquad (4)$$

we obtained the results shown in Table A-2.

c. STATEWIDE REGRESSION ANALYSIS

It was decided to perform a stepwise regression analysis in order to arrive at the relationship between fuel consumed for homeheating and degree-days, per capita income, fuel price, and the average size of a housing unit by state. Due to the fact that considerable data are available on gas usage in publications of the American Gas Association, the analysis was performed for gas usage.

Walden used average therms for homeheating per homeheating customer as the dependent variable (y). These were obtained by state by multiplying the total residential gas use, by the percentage of gas used for homeheating and dividing this by the total number of homeheating customers. The independent variables for each state were obtained from the following sources:

TABLE A-1

ESTIMATION OF DISTILLATE OIL CONSUMED FOR RESIDENTIAL USE - 1970
(thou. barrels)

State	(A) Estimated Distillate Oil Spaceheating	(B) Estimated Distillate Oil Non-Spaceheating	(C) Distillate #1 and #2 for Heating (1)	(D) % of Total #1 and #2
Alabama	128	4	619	21
Alaska	1,560	112	2,232	75
Arizona	30	3	119	28
Arkansas	56	2	493	12
California	469	52	1,375	38
Colorado	298	9	1,229	25
Connecticut	15,984	2,311	18,194	100
Delaware	2,117	201	3,292	70
D.C.	1,393	299	2,847	56
Florida	1,927	205	4,285	50
Georgia	855	11	2,123	41
Hawaii	--	11	179	6
Idaho	2,190	8	2,965	74
Illinois	10,774	445	21,441	52
Indiana	10,180	91	16,402	63
Iowa	5,326	45	6,853	78
Kansas	223	3	576	39
Kentucky	1,741	13	2,118	83
Louisiana	33	3	682	5
Maine	8,700	791	9,406	100+
Maryland	9,853	1,076	12,573	87
Massachusetts	25,678	4,216	51,848	58
Michigan	14,331	224	26,326	55
Minnesota	15,554	157	14,544	100+
Mississippi	38	2	693	6
Missouri	2,494	39	5,809	44
Montana	981	4	1,011	97
Nebraska	1,190	13	2,203	55

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TABLE A-1 (continued)

Nevada	636	28	753	88
New Hampshire	5,600	591	6,931	89
New Jersey	20,952	4,161	41,902	60
New Mexico	74	2	295	26
New York	45,466	15,472	84,870	72
North Carolina	12,767	266	13,311	98
North Dakota	3,301	40	2,839	100^+
Ohio	10,399	172	15,545	68
Oklahoma	30	2	562	6
Oregon	4,949	96	6,246	81
Pennsylvania	29,025	3,299	41,311	78
Rhode Island	4,939	865	7,358	79
South Carolina	3,479	53	4,352	81
South Dakota	2,488	20	2,735	92
Tennessee	1,135	10	1,843	62
Texas	132	13	2,642	5
Utah	367	7	1,138	33
Vermont	3,764	211	4,747	84
Virginia	10,315	845	12,707	88
Washington	9,533	156	11,825	82
West Virginia	955	11	327	100^+
Wisconsin	16,374	220	18,991	87
Wyoming	111	3	637	18
				72%

(1) Fuel Oil Sales, Annual, Bureau of Mines, Washington, D.C.

*$D = \frac{A+B}{C} \times 100\%$, where $D > 100\%$, we have indicated this by 100^+. Except for West Virginia, D is never significantly greater than 100%.

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TABLE A-2

ESTIMATION OF RESIDENTIAL CONSUMPTION OF DISTILLATE OIL FOR SPACEHEATING - 1970

State	# of Oil Burners[1]	Load Factor	Distillate Oil Used for Spaceheating of Equipment Method (thou. barrels)	EPA Method (thou. barrels)
Maine	180,256	0.31	8,326	8,700
New Hampshire	164,128	0.27	6,603	5,600
Vermont	59,294	0.29	2,562	3,764
Massachusetts	1,127,639	0.25	42,005	25,678
Rhode Island	165,733	0.25	6,174	4,939
Connecticut	527,910	0.25	19,665	15,984
New York	1,907,815	0.25	71,066	45,466
New Jersey	1,022,608	0.22	33,521	20,952
Pennsylvania	1,084,361	0.22	35,545	29,025
Delaware	74,932	0.20	2,233	2,117
Maryland	384,297	0.18	10,307	9,853
D.C.	93,902	0.19	2,658	1,393
Virginia	290,924	0.22	9,624	10,315
West Virginia	16,503	0.17	418	955
North Carolina	309,749	0.17	7,846	12,767
South Carolina	67,444	0.12	1,206	3,479
Georgia	39,689	0.13	769	855
Florida	186,418	0.05	1,389	1,927
Michigan	477,750	0.25	17,796	14,331
Ohio	247,013	0.22	8,097	10,399
Indiana	280,125	0.22	9,182	10,180
Illinois	476,901	0.23	16,343	10,774
Wisconsin	348,148	0.25	12,969	16,374
Minnesota	319,709	0.27	12,862	15,554
Iowa	146,009	0.23	5,004	5,326
Missouri	122,442	0.19	3,466	2,494
Kansas	10,219	0.20	305	223
Nebraska	53,286	0.25	1,985	1,190

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TABLE A-2 (continued)

North Dakota	53,507	0.26	2,073	3,311
South Dakota	44,064	0.25	1,641	2,488
Kentucky	43,039	0.20	1,283	1,741
Tennessee	48,605	0.15	1,086	1,135
Alabama	14,941	0.11	245	128
Mississippi	4,863	0.25	181	38
Arkansas	6,345	0.15	142	56
Louisiana	18,554	0.09	249	33
Oklahoma	8,372	0.16	200	30
Texas	38,058	0.11	624	132
Montana	18,472	0.25	688	981
Idaho	75,838	0.24	2,712	2,190
Wyoming	10,032	0.26	387	111
Colorado	23,491	0.21	735	298
Utah	30,621	0.22	1,004	367
Nevada	22,663	0.24	810	636
New Mexico	6,513	0.18	175	74
Arizona	19,318	0.13	375	30
Washington	400,426	0.27	16,109	9,533
Oregon	223,833	0.23	7,670	4,949
California	74,604	0.16	1,779	469

Source: (1) Fuel Oil and Oil Heat (October 1972).

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Average degree-days from the 1970 Statistical Abstract of the U.S.

Per capita income from the 1971 Statistical Abstract of the U.S.

Price of residential gas from the 1971 Gas Facts, American Gas Association

Average rooms/housing unit from the 1970 Census of Housing, General Characteristics

In the stepwise regression, the variables were selected in the following sequence: degree-days (x_1), price (x_2), per capita income (x_3), average rooms/housing unit (x_4). The final equation was:

$$y = 0.00011\ x_1 - 0.34450\ x_2 + 0.00021\ x_3 + 0.22904\ x_4 - 0.93373$$

where y is expressed in thousand therms/homeheating customer

x_1 is expressed in degree-days

x_2 is expressed in dollars per thousand cubic feet (or million Btu)

x_3 is expressed in dollars

x_4 is expressed in average number of rooms

The adjusted multiple correlation coefficient R^2 equalled 0.672. The F-statistic, F(4.45), was 25.377, which indicates a 0.995 confidence level. The adjusted standard error of estimate was 0.205 and the range of residuals was 0.893. The t-statistics for the coefficients showed a 0.9995 confidence level for the coefficients of x_1, x_2, and x_3 and a 0.975 confidence level for the coefficient of x_4.

Leaving out the variable indicating average number of rooms per housing unit we found the R^2 reduced to 0.646 and the adjusted standard error slightly higher, 0.211. The confidence level remained more or less the same. Interestingly, the range of residuals was reduced to 0.860, although the standard error increased. This reduction is not significant enough to warrant deletion of this fourth variable.

The correlation matrix shown in Table A-3 showed no significant intercorrelation of the independent variables.

TABLE A-3

CORRELATION MATRIX

	y	x_1	x_2	x_3	x_4
y	1.000	0.672	-0.193	0.362	0.214
x_1	0.672	1.000	0.196	0.217	0.286
x_2	-0.193	0.196	1.000	0.281	0.276
x_3	0.362	0.217	0.281	1.000	-0.087
x_4	0.214	0.286	0.276	-0.087	1.000

TABLE A-4

RESIDENTIAL DISTILLATE OIL CONSUMPTION BASED ON MULTIPLE REGRESSION EQUATION

State	Thou Barrels Consumed (1970)
Massachusetts	14,896
Maryland	7,048
Missouri	1,234
Washington	4,786
Maine	3,951
Connecticut	10,475

Using the resulting equation and tank wagon prices for #2 fuel oil shown in the 1970 November issue of Fuel Oil and Oil Heat for selected cities and assuming that these prices are representative for the entire state in which the cities are located, we obtain the fuel oil figures shown in Table A-4.

d. METHOD BASED ON HEAT LOSS AND DESIGN RANGE

The Yankee Oilman, March 1973 Fuel Trades Fact Book shows the following formula:

$$\text{Fuel Units Consumed Annually} = \frac{\text{Heat Loss x Annual Degree Days x Use Factor}}{\text{Btu per Fuel Unit x Design Range}}$$

where the heat loss is the hourly amount of Btu's lost per square feet of area multiplied by the total square feet; the use factors are fuel and use dependent and listed in a table in the publication; the design range is defined as the difference between inside temperature (70°F) and the design outside temperature for the area.

Walden obtained the state-by-state data needed to use this formula from the following sources:

(1) Average square feet per housing unit for selected states (needed for heat loss calculations) - Independent Gas Association of America, Comparison of Seasonal Househeating Costs, December 1972.

(2) Design range - "Systematic Study of Air Pollution from Intermediate Size Fossil Fuel Combustion Equipment," Walden Research Corp., Cambridge, Mass.

(3) Degree days - 1970 Statistical Abstract of the United States, U.S. Dept. of Commerce, Washington, D.C.

Other factors were taken from the Yankee Oilman publication in which the formula was shown. The estimated distillate oil used for spaceheating is listed in Table A-5 for selected states.

TABLE A-5

ESTIMATES OF DISTILLATE OIL CONSUMED FOR HOME HEATING
BASED ON A PER HOUSING UNIT REQUIREMENT
ACCORDING TO AVERAGE FT^2

State	Distillate Oil (thou barrels)
Pennsylvania	21,487
Indiana	7,055
Illinois	7,165
Michigan	11,962
Iowa	2,839
Missouri	3,236
Nebraska	833
Georgia	1,123
Florida	2,466
Kentucky	1,683
Tennessee	1,143
Alabama	143
Oklahoma	21
Idaho	1,808
Arizona	33
Washington	11,062

Table A-6 shows a summary of the four methods.

TABLE A-6

SUMMARY OF ESTIMATION METHODS FOR RESIDENTIAL FUEL OIL USED FOR SPACEHEATING

Based on:

	EPA(1)	Equipment(2)	Multiple Regression(3)	Square Feet(4)
Massachusetts	25,678	42,005	14,896	n.a.
Maryland	9,853	10,307	7,048	n.a.
Missouri	2,494	3,466	1,234	3,236
Washington	9,533	16,109	4,786	11,062
Maine	8,700	8,326	3,951	n.a.
Connecticut	15,984	19,665	10,475	n.a.
Florida	1,927	1,389	n.a.	2,466
Alabama	128	245	n.a.	143

(1) EPA Guide for Compiling a Comprehensive Emission Inventory

(2) Fuel Oil and Oil Heat; Intermediate Boiler Study, Walden

(3) Walden Research Corporation

(4) Independent Gas Association of America; Yankee Oilman

2. County Fuel Oil

Walden collected sufficient community-by-community data to perform stepwise regression analyses of the type shown below:

$$\text{Residential gas use} = a_x \text{ degree days} + b_x \text{ median income} + c_x \text{ average rooms per housing unit} + d$$

The regressions were performed on a community-by-community basis for two reasons: (1) the majority of gas companies do not individually service enough counties to provide a significant sample for a regression analysis, (2) it is quite common for a utility to service only a portion of a given county, in which case that utility's sales in the county would not reflect total consumption.

Walden contacted various gas companies across the country to obtain community residential gas sales figures for the year 1970. Table A-7 shows the companies which provided data for the regressions. Detailed degree-day data were obtained from the Climatological Data Center in Asheville, North Carolina (6).

TABLE A-7

GAS COMPANIES WHICH PROVIDED RESIDENTIAL GAS DATA

Utility	Area Serviced
Wisconsin Gas Co.	Southern Wisconsin
Northern Illinois Gas Co.	Northern Illinois
Boston Gas Co.	Metropolitan Boston
Pacific Gas and Electric Co.	Central California
Southern Union Gas Co.	Texas, New Mexico, Arizona
East Ohio Gas Co.	Metropolitan Cleveland

Median income figures for all communities with populations over 2500 were obtained from the Census of Population (7). Average number of rooms per dwelling unit was obtained in the 1970 Census of Housing (8) for all communities over 2500.

The regression results are summarized in Table A-8 and discussed in detail below:

In Wisconsin, where 21 communities were analyzed, the first variable selected in the stepwise regression analysis was average number of rooms per dwelling unit (R^2 = .581). The second was annual degree-days. When this was entered into the regression, the multiple correlation coefficient increased to .687. There was a wider range in the size of dwelling units than there was in the number of degree-days for the municipalities considered. In using degree-days as a variable, it is important to note that the degree-day figures are taken from the nearest weather station which may be as much as thirty miles away. Degree-days also do not account for a wind chill factor, which can be very significant in many cases.

When gas use for residential space heating only was used as the dependent variable in these same 12 communities, the order of significance for the independent variables was not changed, but the correlation coefficients in each case were increased slightly.

Southern Union Gas Co. provided Walden with data for 22 communities in Arizona, New Mexico, and Texas. The most significant variable in this case was degree-days (R^2 = .755). For this area, the degree-day variation was very large, ranging from 1558 to 7076 degree-days. The second most significant variable, average number of rooms, varied by only .7 rooms, from smallest to largest.

The third analysis was performed for 23 communities in the Cleveland, Ohio area. Because these communities were all within thirty miles of one another, the range of degree-days was almost negligible. There were only three stations in the area from which degree-day readings could be used, further reducing the significance of the degree-day data. Median income was selected as the most significant independent variable.

California data for 87 communities were obtained. Median income explained a major proportion of the variability in fuel use for this analysis. The most striking characteristic about these communities was that the degree-day figures did not exceed 3200, and, in most cases, they ranged

TABLE A-8

RESIDENTIAL GAS USE RESULTS

State	Intercept	Variable #1	Variable #2	Variable #3	R^2	Adjusted St. Error	Mean
Wisc.	-45.237	Rooms (48.237)			.581	25.625	224.754
Wisc.	-243.642	Rooms (53.146)	D. Days (.0227)		.642	24.963	
Wisc.	-279.969	Rooms (7.322)	D. Days (.0399)	Income (.0125)	.687	24.775	
Wisc.*	-60.231	Rooms (49.459)			.619	24.205	
Wisc.*	-299.145	Rooms (55.319)	D. Days (.0273)		.734	21.353	
Wisc.*	-323.688	Rooms (21.572)	D. Days (.04002)	Income (.00922)	.750	21.918	
So. Union	61.382	D. Days (.0109)			.755	12.346	103.423
So. Union	-71.2101	D. Days (.0114)	Rooms (27.1936)		.799	11.449	
Ohio	89.39977	Income (.00981)			.616	18.428	218.808
Calif.	41.56526	Income (.00557)			.676	9.927	105.790
Calif.	17,74512	Income (.00587)	D. Days (.00844)		.717	9.402	
Calif.	-3.64337	Income (.00473)	D. Days (.00791)	Rooms (7.13864)	.733	9.106	
Ill.	74.67360	Income (.00543)			.610	12.856	149.324
Ill.	89.10452	Income (.00629)	Rooms (-4.87662)		.612	12.922	
Mass.	44.17616	Rooms (29.1398)			.320	40.709	218.095
All Groups	61.852	D. Days (.01729)			.510	36.221	145.049
All Groups	-95.172	D. Days (.01351)	Rooms (33.326)		.674	29.544	
All Groups†	65.284	D. Days (.0157)			.527	32.248	138.502
All Groups†	-79.537	D. Days (.0128)	Rooms (30.4079)		.666	27.089	

* Spaceheating Only

† Less Boston

from 1500 to 2500 degree-days. This meant that a much higher proportion of total gas use in these communities was devoted to non-space-heating applications than in any of the previous areas analyzed. Degree-days, in general, do not explain the variability in residential gas use in warmer climates. Mean income was the most significant variable in this case (R^2 = .676). The correlation coefficient between degree-days and gas use was only .022.

Data for 68 communities in Northern Illinois were obtained from the Northern Illinois Gas Co. More than three quarters of these communities were in the immediate Chicago area. This limited the degree-day figures to only five weather stations in the area with a total range of difference of less than 500 degree-days. In compiling the degree-day data in this case, it was exceedingly difficult to assign a certain weather station's degree-day figure to a given community with any assurance of accuracy. Secondly, the Chicago area is generally subjected to strong winds coming off Lake Michigan during the normal heating season. This is no doubt a significant factor in gas consumption for space heating purposes, which our degree-day figures did not reflect. Median income was the most significant variable in this case (R^2 = .610).

The final group studied included 19 communities in the Boston area. The most significant variable in this case was average rooms per dwelling unit with a correlation coefficient of .320. In the Boston area, unlike the other areas studied, gas is not the primary heating fuel. Furthermore, the proportion of older dwelling units in the Boston area is probably much higher than in the other areas studied. These older units probably have spaceheating characteristics which differ significantly from those in newer housing units, due to boiler conversions and consequent diminished combustion efficiency.

A regression was performed on all six groups combined. This gave a total of 231 communities. As might be expected, the degree-days represented the most significant variable because of the wide range of readings available on a nationwide basis from below 1500 to over 8000 degree-days. The multiple correlation coefficient produced at this first step was .510. With the addition of the average rooms per dwelling unit, the correlation

coefficient was markedly improved to .674. Median income was not introduced into the regression because as the correlation matrix (Table A-9) shows, there is a very high correlation between average rooms per dwelling unit and median income (r = .806) indicating that median income is not an independent variable.

TABLE A-9

CORRELATION MATRIX FOR SIX GROUPS COMBINED

	Gas Use	Degree-Days	Median Income	Rooms Per D.U.
Gas Use	1.000	.717	5.72	.637
Degree-Days	.717	1.000	.329	.361
Median Income	.572	.329	1.000	.806
Rooms Per D.U.	.637	.361	.806	1.000

A regression was also performed on all the groups excluding the Metropolitan Boston communities. This left a total of 212 communities in the regression. The results, however, were not as good as those for all six groups. The first-chosen variable, which again was degree-days, gave a correlation coefficient of .527. When the next variable, average rooms per dwelling unit, was entered into the regression, the multiple correlation coefficient increased to only .666, lower than for all 231 communities, with both variables entered into the regression.

Using the formula:

residential Dist. Oil (gallons) = [(.01288 x degree-days + 30.41 x avg. rooms per housing unit - 79.54)/ .14] x # of housing units

Walden calculated residential distillate oil use for all counties in Maine (see Table A-10) and compared the sum of these figures with the Maine state total obtained by using the EPA method (see Table A-1, column C). The figures were within 12% of each other. Similar calculations were performed for Massachusetts, where the two state totals differed by less than 1%. These calculations increased our confidence in the selected method to be used to calculate residential distillate oil by county.

TABLE A-10

RESIDENTIAL DISTILLATE OIL BY COUNTY - MAINE
(thou gallons)

County	Distillate Oil
Androscoggin	29,203
Aroostook	30,851
Cumberland	64,903
Franklin	9,365
Hancock	13,853
Kennebec	34,706
Knox	12,255
Lincoln	8,285
Oxford	15,946
Penobscot	44,396
Piscataquis	6,788
Sagadahoc	9,189
Somerset	16,591
Waldo	8,565
Washington	11,851
York	38,910
Total Maine	355,657
Total Maine (EPA Method)	398,622

REFERENCES - APPENDIX A

1. 1970 Census of Housing - Detailed Characteristics, U.S. Dept of Commerce, Washington, D.C.

2. Statistical Abstract of the United States, 1970, U.S. Dept. of Commerce, Washington, D.C.

3. Guide for Compiling a Comprehensive Emission Inventory, Environmental Protection Agency (June 1972).

4. Systematic Study of Air Pollution from Intermediate Size Fossil-Fuel Combustion Equipment, Walden Research Corp., Cambridge, Mass. (1971).

5. Communication with Mr. Griffith, Department of Statistics, American Gas Association, Arlington, Virginia.

6. Climatological Data, Monthly Summarized Station and Divisional Data, U.S. Dept. of Commerce, National Oceanographic and Atmospheric Administration, Ashville, North Carolina.

7. 1970 Census of Population - General Social and Economic Characteristics, U.S. Dept. of Commerce, Washington, D.C.

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APPENDIX B

REGRESSION ANALYSIS OF COMMERCIAL USE OF OIL FOR VARIOUS SUBCATEGORIES

B-1 GENERAL

It was found that the commercial category consisted of such a great variety of business enterprises and institutions, that it would be inaccurate to use employment as the distributive factor to allocate total commercial fuel oil by county. It was therefore decided to analyze the relationship between fuel oil use and employment for several subcategories in order to determine the fuel oil use for these categories in a direct way, based on the number of employees in each subcategory in each county (1).

Fuel oil consumption of individual companies and institutions was extracted from the NEDS files and basically compared to employment data. This initial analysis has indicated fairly good correlations, and has reconfirmed the fact that the various subcategories use fuel oil in very different ways. The independent variable in these single variable regressions was employment, but the slope and intercept of the regression lines differed considerably.

It is recommended that this analysis be refined and pursued for other categories as well. The initial results are discussed below.

B-2 HOSPITALS

The NEDS files provided Walden with a significant sample of hospitals using fuel oil in Baltimore, New Hampshire and Massachusetts. Staff data on hospitals were obtained from the American Hospital Association (2).

For the 14 hospitals in Baltimore, fuel oil use was correlated with an R^2 of .91 to employment. For the 15 hospitals in New Hampshire, the R^2 was .86, and for the 40 Massachusetts hospitals (excluding state hospitals), the R^2 was .68. Data for all three states were combined, resulting in a correlation coefficient of .81 and the regression line:

$$\text{fuel oil use (thou. gallons)} = .715 \times \text{employees (thou.)} + 208.5$$

B-3 SCHOOLS

Fuel oil use was available from NEDS for schools in Baltimore and Massachusetts and was compared to employment data for the specific schools (3, 4). The correlation coefficient, R^2, was .44 for Baltimore and .58 for Massachusetts. Due to the fact that many of the Baltimore schools used fuel oil as a secondary fuel, it was decided to use the Massachusetts results based on a sample size of 17. The regression line was:

fuel oil use (thou. gallons) = 2.97 x employees (thou.) + 76.2

B-4 COLLEGES

Fuel oil use for colleges in Massachusetts, New Hampshire and Maine was available from NEDS. Staff data for these colleges were obtained from an HEW survey of employees in institutions of higher learning (5).

The Massachusetts data showed an R^2 of .76 for 15 sample points. The New Hampshire and Maine data were combined and showed an R^2 of .65 for a total sample of 10 colleges. Finally, the data for all three states were combined, producing an R^2 of .67 and the regression line:

fuel oil use (thou. gallons) = .546 x employees (thou.) - 40.9

B-5 LAUNDRIES

Fuel oil use for laundries available for Baltimore and Boston was correlated with employment (6). Originally, very poor correlations were obtained. Walden analyzed the Baltimore data, and found that many laundry store fronts were included in the computer listing of sources in Baltimore. Walden proceeded to separate out all the dry cleaning plants, SIC 7211, 7216 and 7217, and re-ran the regression analysis on dry cleaning plants only. An R^2 of .72 was obtained for a total of 8 sample points. It is obvious that more data need to be collected for this subcategory. In spite of this, it was decided to use the resulting regression line:

fuel oil (thou. gallons) = .355 x employment (thou.) + 8.4

B-6 HOTELS

Walden was not able to obtain employment data for the various hotels reported as point sources. Therefore, a roundabout method was developed to derive fuel oil consumed by hotels from employment data.

Fuel oil use by hotels obtained from NEDS and from the public relations offices of the Hilton Hotels was compared to the number of rooms for those hotels (7), resulting in an R^2 of .96 for a total of 18 sample points. Then, the number of hotel rooms in each state was correlated with the number of hotel employees in each state (8) resulting in an R^2 of .98. State by state rooms/employees ratios were developed (see Table B-1) and the resulting model consists of the regression line:

$$\text{fuel oil (thou. gallons)} = 1.09 \times \text{rooms} + 41.5$$

where rooms are determined by dividing the employment in hotels in each county by the appropriate state ratios.

Example: To demonstrate the proportion of fuel oil used by these subcategories and residential apartment buildings, Walden calculated the fuel oil used in Massachusetts by the enterprises and institutions discussed above, using the statewide coal, distillate oil, residual oil and gas distribution shown in Section III of this report. The results are shown in Table B-2.

TABLE B-1

ROOM/EMPLOYEE RATIOS FOR HOTELS BY STATE

State	Ratio	State	Ratio	State	Ratio
AL	.28	MI	.27	UT	.22
AK	.21	MN	.35	VT	.26
AZ	.29	MS	.28	VI	.29
AR	.39	MO	.30	WA	.26
CA	.27	MT	.20	WV	.29
CO	.29	NB	.26	WI	.31
CN	.37	NV	.80	WY	.20
DE	.13	NH	.23		
DC	.58	NJ	.27		
FL	.34	NM	.23		
GA	.33	NY	.31		
HI	.56	NC	.22		
ID	.21	ND	.21		
IL	.32	OH	.31		
IN	.30	OK	.22		
IO	.28	OR	.29		
KA	.23	PA	.36		
KY	.30	RI	.36		
LA	.38	SC	.28		
ME	.16	SD	.16		
MD	.29	TN	.28		
MA	.34	TX	.32		

TABLE B-2

1970 COMMERCIAL USE OF FUEL OIL IN MASSACHUSETTS
(Thou. Barrels)

	Distillate	Residual
Hospitals	449	663
Schools	299	441
Colleges	221	326
Laundries	35	51
Hotels	274	404
Apartments	1,802	809
Σ 6 categories	3,080	2,694
Total Commercial	14,219	19,482

REFERENCES - APPENDIX B

1. County Business Patterns, U.S. Dept. of Commerce, Washington, D.C.
2. American Hospital Association Guide to the Health Care Field, American Hospital Association, Chicago, Ill., 1970.
3. Annual Report of Faculty Racial Composition, Baltimore City Public Schools, Office of Research Reports and Statistical Records, Center for Planning, Research and Evaluation, Sept., 1972.
4. Obtained from files of the Department of Education of the Commonwealth of Massachusetts.
5. Number and Characteristics of Employees in Institutions of Higher Learning, 1966-1967, Dept. of Health, Education and Welfare, Washington, D.C.
6. Dun & Bradstreet computer print-out provided to Walden by the EPA.
7. Hotel and Motel Red Book, American Hotel and Motel Association, New York, N.Y.
8. Hotels, Motor Hotels and Motels, Census of Selected Service Industries, 1967 Census of Business, U.S. Dept. of Commerce, Washington, D.C.

APPENDIX C

REGRESSION ANALYSIS OF URBAN VS RURAL DRIVING PATTERNS ON A COUNTY-BY-COUNTY BASIS

Stepwise regression analyses were performed on county-by-county data to find a relationship between miles traveled in each county per registered car and the socio-economic factors and highway patterns for each county. The independent variables collected for this purpose were: percentage of population considered rural, miles of interstate highways, per capita income, miles of state highways, and population density.

The percent of county population considered rural was obtained from the 1970 Census of Population (1). The number of miles of interstate highways in given counties was obtained from the Federal Highway Administration (2). Per capita income by county was obtained from the Department of Commerce (3). State highway mileage by county was obtained from the California Highway Department for California only (4). Population density by county was obtained from the 1970 Census of Population (1). Miles traveled per registered car for each county was derived from total county vehicle mile figures, provided by the highway departments of the states involved and county car registration totals supplied by R. L. Polk of Detroit, Michigan. The results of the regression analyses are summarized in Table C-1 below.

The results were very discouraging. Not only were the multiple correlation coefficients low, but the intercepts of the regression lines and the standard errors were extremely large. In all states, there are some counties with very extreme patterns. When we eliminated the data for the six counties in California, which showed over 30,000 miles traveled a year per vehicle, a greatly increased R^2 (from .297 to .440) and a sharply reduced standard error (from 9423 to 2377) were observed. Similar changes are observed when some of the extreme data are eliminated in other states.

TABLE C-1

RESULTS OF REGRESSION ANALYSIS TO DETERMINE DIFFERENTIATION IN RURAL VS URBAN DRIVING PATTERNS

State	R^2	F-stat.	Standard Error	1st Var. Selected	1st Var. Coeff.	1st Var. t-stat.	2nd Var. Selected	2nd Var. Selected	2nd Var. t-stat.	Inter-cept
Calif. (58)	.297	12.3	9,423	% rural	215	4.889	p. cap. income	3.3	1.512	-6,983
Wash. (39)	.337	9.9	7,169	% rural	186	4.213	interest. miles	146	2.976	5,546
Kansas (100)	.379	30.5	4,405	% rural	112	7.420	interest. miles	183	4.700	7,622
Iowa (99)	.415	34.8	3,840	% rural	108	6.869	interest. miles	178	6.357	7,790
Georgia (100)	.245	16.4	9,762	% rural	229	.5460	interest. miles	193	85.62	5,921
Maine (16)	.181	2.0	2,257	% rural	56	1.999	interest. miles	27	1.079	11,419
Arkansas (75)	.300	16.2	4,586	% rural	123	5.112	interest. miles	179	4.017	9,100
Florida (67)*	.104	7.6	649	pop. density	-.81	-2.749	step eliminated	--	--	1,444

*Dependent variable is gallons per car registered instead of miles per car registered.

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When a large percentage of the sample points have to be eliminated in a regression analysis, the significance of the regression is sharply reduced. In Georgia, for example, the miles traveled per car range from 3167 for Chattahoochee County (27% rural) to 56,976 miles for Charlton County (100% rural). Furthermore, for counties classified by the census as 100% rural we find very dissimilar miles travelled per car (see Table C-2 below). This variability is probably due to factors relating to the geographical location of the counties with respect to industrial regions; factors which are not easily quantified.

TABLE C-2

DRIVING PATTERNS FOR SELECTED 100% RURAL COUNTIES IN GEORGIA

County	Miles/Car	Interstate Miles	Per Cap. Income
Atkinson	37,229	0	1,828
Baker	27,921	0	1,696
Brantley	48,170	0	1,820
Calhoun	23,579	0	1,875
Charlton	56,976	0	1,988
Clay	20,701	0	1,745

In short, the above analyses showed too vague a correlation between driving patterns and rural/urban factors to be implemented in this project. It did show that the vehicle miles per registered car fluctuate tremendously from county to county, giving us a rough idea of the extent of our estimation errors in countywide gasoline consumption when car registration figures are used for distributive purposes instead of the preferred vehicle miles figures. It is reassuring to note that many states have now started collecting vehicle-miles data on a county level. It would

be of interest to the EPA to indicate the usefulness of these data to the proper state highway department officials, in order to avoid having to use car registrations to distribute statewide gasoline use over the various counties.

To compensate for these errors to some extent, Walden summarized the average miles driven per vehicle by four categories: 25% rural or less, 26 to 50% rural, 51 to 75% rural and more than 75% rural, leaving out the extreme values that varied by more than 50% from the mean of the total sample in each state. The results are shown below in Table C-3.

TABLE C-3

AVERAGE MILES PER VEHICLE BY % RURAL CATEGORIES

State	Entire Sample	Modified Sample	≤ 25%	26-50%	51-75%	76-100%
California	15,152	13,047	10,729	12,202	14,803	16,920
Washington	18,722	17,092	11,940	15,793	15,778	21,855
Kansas	16,155	15,179	10,706	13,622	15,306	17,225
Iowa	15,643	14,604	11,468	12,141	15,501	15,862
Georgia	23,140	20,262	13,185	17,680	19,687	22,461
Maine	15,261	15,261	11,210	15,396	14,876	15,995
Arkansas	18,652	17,932	11,039	15,908	18,144	19,458
Seven State Avg.		16,709	11,217	14,572	17,238	19,261
Indexes		100	67	87	103	115

The method for countywide allocation will be as follows:

(1) If vehicle miles are available by county, use vehicle miles for distributive purposes on statewide gasoline for LDV figures.

(2) Otherwise multiply the LDV registrations in each county by the appropriate miles/vehicle index according to the percentage of the population considered rural in that county.

(3) Summarize these results for all counties to obtain a state total.

(4) Use the modified county registrations, thus derived, to distribute the statewide gasoline for LDV figures.

REFERENCES - APPENDIX C

1. 1970 Census of Population, Characteristics of the Population, Number of Inhabitants, U.S. Dept. of Commerce, Washington, D.C.

2. Computer listing obtained from the Interstate Reports Branch of the Federal Highway Administration, Washington, D.C.

3. Computer listing obtained from the Regional Economics Division of the Department of Commerce, Washington, D.C.

4. Historical State Highway, County Road and City Street Statistics, 1957-1970, State of California, Department of Public Works, Division of Highways, December 1971.

APPENDIX D

ANALYSIS OF AN ALTERNATE METHOD TO ALLOCATE MOTOR FUEL USED BY HEAVY-DUTY VEHICLES ON A COUNTY-BY-COUNTY BASIS

An alternate method to allocate gasoline and diesel used by heavy-duty vehicles to counties was analyzed. It must be emphasized that this method was not incorporated into the computer program and that data were not collected for this method for 1972.

The Federal Highway Administration provided state-by-state totals of vehicle miles traveled by trucks on interstate urban and rural highway systems. It also provided estimates of the percentage of all trucks on interstate highways which are diesel, distinguishing between urban and rural interstate systems. By applying these respective percentages to the urban and rural interstate highway truck vehicle mile totals for each state, we derived estimates for total vehicle miles driven by diesel trucks on both urban and rural interstate highways in each state.

Using county level interstate urban and rural mileage totals, also provided by the F.H.W.A., the state vehicle-mile totals can be allocated to counties. Dividing the county diesel interstate vehicle mile totals by 5.1 MPG (1), we arrive at an estimate of total gallons of diesel fuel consumed by trucks on interstate highways on a county basis. This would be in the form of a rural and an urban subtotal.

A similar procedure can be employed to estimate gasoline consumed by heavy-duty vehicles on interstate highways. Using this method, it is first assumed that all heavy-duty vehicles not using diesel, use gasoline.

This is justified, since less than .1% of the truck traffic on interstates is propane or LPG. It is therefore assumed that total interstate highway truck vehicle miles minus the diesel vehicle mile total will be the gasoline truck vehicle mile total. This statewide gasoline vehicle mile figure is then allocated to the various truck weight classes by using truck registrations by weight class (2), adjusted to reflect the differing average miles driven per year by trucks of different weight categories (3). At this point, the vehicle mile total for trucks weighing less than 6,000 lb (LDV) is eliminated from further calculations. The weight class vehicle mile subtotals can now be divided by their respective mile per gallon estimates which have been derived by Walden previously (see page 3-15). The resulting weight subtotals of gasoline consumption can now be combined and allocated to counties according to interstate mileage in each county, as in the diesel method.

The above methods provide gasoline and diesel totals by county consumed by heavy-duty vehicles on interstate highways. It is necessary to allocate the remaining motor fuel, which is not consumed on interstate highways, to the various counties as well.

1. Diesel

   a. Subtract the interstate diesel consumed in the U.S. from the total diesel consumed on highways in the nation.

   b. Allocate the resulting diesel figure to each state, by using the state percentage of the original national total.

   c. Allocate the state diesel figure obtained in Step b to the various counties by means of total truck registrations.

The total diesel consumed by heavy-duty vehicles in that county is the sum of the diesel consumed on interstate highways and the results of Step c above.

2. Gasoline

a. Subtract the heavy-duty gasoline use on interstate highways from the total use of heavy-duty motor fuel in that state.

b. Subtract the state diesel consumption total (both interstate and non-interstate) from the state total resulting from Step a. This gives the consumption of gasoline by HDV on non-interstate roads in each state.

c. Allocate the state gasoline total obtained in Step b to the various counties by means of total truck registrations.

The total gasoline consumed by heavy-duty vehicles in that county is the sum of the gasoline consumed on interstate highways and the results of Step c above. These modifications should eliminate the occurrence of negative totals for county heavy-duty vehicle gasoline and diesel use, which could occur in counties with high interstate mileage and small truck registration totals. The results of these new methods applied to the thirteen test counties for the year 1971 are shown in Table D-1, and can be compared with the results using the existing methods for the same year in Table D-2.

This method represents a significant improvement over the method used so far by Walden to allocate gasoline and diesel use by county. It is found to have the following drawbacks, however:

a. It is a very time-consuming method with regard to the required input preparation.

b. The required data are not presently available on a yearly basis.

TABLE D-1

COUNTY FUEL CONSUMPTION RESULTS FOR 1971 USING INTERSTATE VEHICLE MILE METHODS
(Thousands of Gallons)

County	Heavy-Duty Gasoline Non-Interstate	Heavy-Duty Gasoline Interstate	Total Heavy-Duty Gasoline	Diesel Interstate	Diesel Non-Interstate	Total Diesel	Total Light-Duty Gasoline
Jefferson	26,374	3,183	29,557	6,249	5,656	11,905	282,469
Los Angeles	150,729	35,651	186,380	20,820	61,274	82,094	3,072,326
San Diego	35,023	21,355	56,378	14,997	14,237	29,234	593,401
Boulder	5,850	00	5,850	00	1,404	1,404	66,404
Palm Beach	14,521	1,180	15,701	3,365	3,106	6,471	162,522
Baltimore City	17,078	1,133	18,211	2,945	6,980	9,925	508,733
Franklin	2,143	2,067	4,210	4,572	674	5,246	22,521
Worcester	13,501	4,619	18,120	12,124	4,246	16,370	224,129
St. Louis County	5,958	12,912	18,870	37,729	1,860	39,589	141,065
Belknap	998	408	1,406	574	354	928	15,791
Minnihaha	3,872	983	4,855	3,085	991	4,076	51,375
Galveston	4,094	1,457	5,551	5,853	1,875	7,728	69,540
King	39,543	5,656	45,199	19,716	9,052	28,768	427,071

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TABLE D-2

COUNTY CONSUMPTION OF MOTOR FUELS BY HEAVY AND LIGHT-DUTY VEHICLES USING EXISTING METHODS* - 1971

County	Heavy-Duty Vehicle Gasoline Consumption	Heavy-Duty Vehicle Diesel Consumption	Light-Duty Vehicle Gasoline Consumption
Jefferson	29,960	15,790	181,400
Los Angeles	154,800	171,300	2,731,000
San Diego	34,860	39,800	499,000
Boulder	6,035	4,240	55,120
Palm Beach	17,250	8,674	143,900
Baltimore	34,190	19,490	467,900
Worcester	18,580	310,800	11,860
Franklin	2,750	26,470	1,883
St. Louis	10,400	5,194	87,070
Belknap	1,030	987	19,500
Minnehaha	2,466	2,765	25,230
Galveston	5,722	503	71,080
King	32,880	24,040	469,100

*See page

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